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This report presents results of a study to develop national and regional background information necessary for the accurate assessment of Hydrocarbon Emissions from Ship and Barge Loading and Unloading of Gasoline and Crude Oil. The report assesses national marine transportation patterns of crude oil and gasoline, projected patterns through 1985. Marine terminal operations, sources of hydrocarbon emissions, operational control technology, estimates of national hydrocarbon losses from marine terminal operations, and potential emission reductions resulting from applying modified operating procedures.

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ABSTRACT

The loading and unloading of volatile hydrocarbon liquids at marine terminals is known to be a source of hydrocarbon emissions. This report presents the results of an in-depth study for EPA to assess the effectiveness of marine terminal emission control by modification in operating procedures as an alternative to vapor recovery systems. Topics addressed in the final report include national marine transportation patterns of crude oil and gasoline, projected patterns through 1985, marine terminal operations, sources of hydrocarbon emissions, operational control technology, estimates of national hydrocarbon losses from marine terminal operations, and potential emission reductions resulting from applying modified operating procedures. The purpose of this report is not to recommend major changes in ship and barge operating procedures, but rather to point out the possible advantages of some operating procedures and the potential hydrocarbon emission reduction which may be achieved through their use. Additional studies will need to be conducted to establish the exact benefits of each operational control procedure. This study was completed through the helpful aid of people representing the petroleum and marine industries, trade associations, and government agencies.

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1.0 SUMMARY AND CONCLUSIONS

This report presents the results of a study for the EPA to assess the effectiveness of modified operating procedures as an alternative to vapor recovery systems for controlling hydrocarbon emissions associated with marine transfer operations. This section summarizes the information included in the report. Section 1.1 is a summary of the study's findings, Section 1.2 presents the conclusions developed from these findings, and Section 1.3 lists areas where further study is recommended.

1.1 Summary

The information developed by Radian in this study are presented here in the same manner as they are organized in the report. The sections included are listed below.

- Background Information
- Crude Oil Movements
- Gasoline Movements
- Projected Trends in Movements
- Effectiveness of Operational Control Techniques
- Estimates of National Hydrocarbon Losses from Marine Operations

1.1.1 Background Information

The section concerning background information represents a brief overview of marine transportation in the petroleum industry, marine terminal operations, and hydrocarbon emissions generated at marine terminals. The background information was compiled from a number of sources, including personal contacts with personnel from the oil refining and marine transportation industries. Important facts included in this section are condensed below:

- In 1975 water carriers accounted for 10 percent of the domestic receipts and 74 percent of the foreign receipts of crude oil at U.S. refinery centers. Overall, marine transportation accounted for 31 percent of crude oil receipts at refineries.
- Statistics for 1975 show that 9.5 percent of domestic gasoline shipments and virtually all (97.8 percent) of imported gasoline shipments were made by water carriers. Overall, marine transportation accounted for 12 percent of the gasoline transported to U.S. bulk terminals.
- The average cost of transporting crude and gasoline by tanker ranges from $0.15 to $0.40 per thousand barrel miles. For barges the average cost ranges from $0.40 to $1.50 per thousand barrel miles.
- Basically two operations occur at the major marine terminal of refining centers: the unloading of crude oil and petroleum products, and the loading of crude oil and petroleum products. Very little crude is loaded at one refining center for transport to another.

- **Hydrocarbon emissions are generated at marine terminals when volatile hydrocarbon products are either loaded onto or unloaded from ships and barges. Loading emissions result from the displacement to the atmosphere of hydrocarbon vapors residing in empty vessel tanks by products being loaded into the vessel tanks. Unloading emissions are hydrocarbon vapors displaced during ballasting operations at the unloading dock following the delivery of a volatile hydrocarbon liquid cargo such as crude oil or gasoline.**

1.1.2 Crude Oil Movements

Statistical information on crude oil movements was provided primarily by government agencies and trade associations. The major points of this section are summarized below.

- Historically the four major U.S. refining centers have enjoyed a relatively stable supply of crude oil. The East Coast has imported most of its crude with supplements from the Gulf Coast. The Midcontinent refineries have depended for the most part on pipeline crude from Canada, Texas, and Louisiana. The Gulf Coast and West Coast have normally received domestic crude by pipeline and imported crude by tanker.

- The cutback of Canadian crude to Midcontinent refineries will force refineries in this area to either transport crude by barge up the Mississippi River or rely on transmission from any of three proposed West Coast pipelines. Economic and environmental problems are hampering the three proposed pipelines. Therefore, an increase in barge transport of crude oil on the inland waterways appears probable.

- The production of North Slope crude will result in America's first major marine terminal for crude oil loading at Valdez, Alaska. The sour crude will be shipped to West Coast refineries, with any excess destined for Gulf Coast refineries via the Panama Canal. By the mid-1980's refinery growth on the West Coast will mean that all North Slope crude can be handled in this region.

- Even with production of North Slope crude, U.S. domestic production will continue to decline. This decline will be offset by increasing imports from Africa and the Middle East to the Gulf Coast and East Coast.

1.1.3 Gasoline Movements

Most of the information used in determining marine transportation patterns for gasoline was provided by trade associations and government agencies. The information is summarized below.

- Almost all (97 percent) of the gasoline transported by ship and barge is loaded on the Gulf Coast. Virtually all of this gasoline is shipped to the East Coast by tanker and to the Midcontinent by barge.

- **The growing U.S. demand for finished petroleum products has resulted in increasing imports. In 1974 the United States imported a total of 885 million barrels of finished petroleum products, 85 percent of which was received at the East Coast. Gasoline accounted for 8.4 percent of the total finished petroleum products imported in 1974.**

1.1.4 Projected Trends in Movements

In projecting movements of crude oil and gasoline by marine transportation, two supply and demand scenarios were modeled after similar energy scenarios developed by the FEA. The projections developed under the two scenarios are included below.

- For maximum refinery growth, the 1985 refinery receipts of crude oil will rise to 6.14 billion barrels. Slightly more than 50 percent (3.1 billion barrels) will be imported by tanker, predominantly to the East Coast and Gulf Coast. Marine transport of gasoline from the Gulf Coast by tanker to the East Coast and by barge to the Inland Waterways and Great Lakes area will continue to increase to offset growing gasoline demands. Gasoline imports may decline under maximum refinery growth.

- For minimum refinery growth, the 1985 refinery receipts of crude oil will increase to approximately 5.8 billion barrels. Only 26 percent (1.48 billion barrels) will be imported by tanker, with most of it arriving at the East Coast and Gulf Coast.

Marine transport of gasoline from the Gulf Coast by tanker to the East Coast and by barge to the Inland Waterways and Great Lakes area will increase at a slower rate. Tanker imports of gasoline to the East Coast should increase steadily.

1.1.5 Effectiveness of Operational Control Techniques

An investigation of operational control techniques indicates that there is a large potential for using modifications in existing marine terminal operating procedures as a means of controlling marine terminal emissions. This potential reduction in emissions is based on emission factors which have been generated by several government and oil industry studies, and represent the best information presently available. A joint government/industry effort is presently underway which is aimed at acquiring more uniformly documented data and more accurate emission factors. Important findings of this investigation are included below.

- Emissions from loading gasoline into uncleaned tankers are 2.4 $lb/10^3$ gal. Because some ships currently practice various degrees of cleaning and ballasting operations, the average gasoline tanker loading emission rate is 1.2 $lb/10^3$ gal.

- The use of tank cleaning, slow initial and final loading, and short loading will potentially lower gasoline loading emissions to less than 0.2 $lb/10^3$ gal. This represents a 92 percent reduction over uncleaned tanker loading and a 83 percent reduction over the typical tanker loading.

- The hydrocarbon emission rate for loading gasoline onto uncleaned ocean barges is 3.3 lb/10^3 gal. The average hydrocarbon emission rate for loading ocean barges with gasoline is 2.7 lb/10^3 gal.

- The use of tank cleaning, slow initial and final loading rates, and short loading will potentially lower gasoline loading emissions for ocean barges to less than 0.2 lb/10^3 gal. This represents a 94 percent reduction over uncleaned ocean barge loadings and a 93 percent reduction over the typical ocean barge loading.

- The hydrocarbon emission rate for loading gasoline into uncleaned inland barges is 4.0 lb/10^3 gal. Because cleaning is not a standard practice on barges, the average barge loading rate is also 4.0 lb/10^3 gal.

- Due to limited flexibility in operating practices the operational control most applicable to inland barges is slow initial loading. Estimated hydrocarbon emissions from slow initial loading gasoline barges is 3.3 lb/10^3 gal. This represents an 18% emission reduction.

- Although limited information is available on crude loading emissions, the emissions from loading volatile crude oil onto tankers and barges are expected to be reduced in the same manner as gasoline loading emissions are by operational control techniques.

- **There are fewer operational control techniques applicable to unloading emissions from ships and ocean barges. The two most promising operational control techniques for unloading emissions from ships and ocean barges are segregated ballast and short ballast. Both techniques potentially have very high control efficiencies which will likely exceed 90 percent.**

1.1.6 Estimates of National Hydrocarbon Losses from Marine Operations

Since reliable emission factors for the loading and unloading of crude oil and for the unloading of gasoline are not available, only hydrocarbon emissions resulting from gasoline loading at marine terminals were estimated. For 1975 the estimated emissions were calculated from interstate gasoline movements discussed in Section 4.2. For 1985 the estimated emissions were calculated from projected gasoline production statistics discussed in Section 4.3. A condensation is presented below.

- Estimated hydrocarbon emissions from gasoline loading operations nationwide amounted to 7,600 tons in 1975. Approximately 6,600 tons of these emissions occurred along the Gulf Coast of Texas, Louisiana, and Mississippi.

- Estimated hydrocarbon emissions from nationwide gasoline loading operations in 1985 are estimated to be approximately 10,000 tons, assuming no change in current operating practices. The application of operational controls is estimated to lower the 1985 emissions to 4,000 tons.

- 1985 nationwide emission reduction due to the application of operational controls is 60 percent. A 64 percent reduction was estimated for the Gulf Coast where the majority of the loading is onto tankers. An 18 percent reduction was estimated for the Great Lakes and Inland Waterways where the majority of the loading is onto barges.

1.2 Conclusions

The following conclusions have been developed from the information generated by this study.

1) Transport of crude oil by water carrier is expected to increase significantly in the ten year period (1975-1985). Tanker deliveries of imported crude oil to the East Coast and Gulf Coast will continue to rise, while tanker deliveries of North Slope crude to the West Coast will stabilize imports to that area. The Inland Waterways and Great Lakes area will be a region of increasing barge activity for crude oil from the Gulf Coast as refiners seek to replace the dwindling Canadian crude supply.

2) Marine transport of gasoline will also increase from 1975 to 1985. Although the West Coast and Gulf Coast will remain relatively gasoline sufficient, East Coast tanker traffic will continue to increase for gasoline arriving from the Gulf Coast and abroad. In addition, barge transport of gasoline from the Gulf Coast to the Inland Waterways will increase as consumer demand outpaces local gasoline production.

3) Three operational control techniques appear applicable to the control of loading emissions from ships and ocean barges: tank cleaning, slow initial and final loading, and short loading. These operational control techniques may potentially lower existing gasoline loading emissions for ships by 83 percent and ocean barges by 93 percent. Note that tank cleaning creates emissions itself, but these emissions will have little impact on inland ambient hydrocarbon levels if the cleaning is conducted out at sea. In addition, short loading may encounter stability problems, but these problems and their solutions are not well defined.

4) The primary operational control technique potentially applicable to inland barges is slow initial and final loading. This control technique is estimated to lower gasoline loading emissions from barges by 18 percent.

5) The most promising operational control techniques for unloading emissions from tankers and ocean barges are segregated ballast and short ballasting. The control efficiency is estimated to be very high.

6) Application of operational controls nationwide in 1985 would potentially reduce the expected national hydrocarbon emissions at transfer terminals from loading gasoline onto ships and barges by 60 percent.

1.3 Recommendations

As a result of this project, several areas have been identified as needing further work to more completely define emissions from marine terminal operations and the potential for applying operational control techniques. The following studies are recommended.

1) A study to obtain detailed information on a regional basis as to the actual breakdown of tank arrival conditions due to cruise history.

2) A sampling program designed to produce accurate emission factors for,

   a. all barge operations including loading and unloading of gasoline and crude oil,

   b. tanker unloading operations for gasoline and crude oil, and

   c. tanker loading operations for crude oil only.

3) A sampling program designed to produce accurate control efficiency information for both loading and unloading operational control techniques applied to crude and gasoline ships and barges.

4) A background study on the cost and various ramifications of applying operational control techniques, including such things as safety, cost, dock time, and additional labor requirements.

2.0 INTRODUCTION

The loading and unloading of volatile hydrocarbon liquids at marine terminals is known to be a source of hydrocarbon emissions. A previous Radian study conducted for the EPA focused on general information concerning marine terminal procedures, emissions, and available control technology, with particular emphasis on the Houston-Galveston port area (EPA Project No. 68-01-4136 Task 1). As a continuing part of the study, it was decided to investigate alternative emission control methods. The EPA commissioned Radian Corporation to conduct a study assessing the effectiveness of marine terminal emission control by modification of operating procedures as an alternative to vapor recovery systems. This report presents the results of that study.

2.1 Objectives

The objectives of this study are to provide the Emission Standards and Engineering Division of EPA with national and regional information on marine terminal operations, including,

- Statistics concerning national geographical patterns for the marine transport of crude oil and gasoline,
- Projected transportation patterns through 1985, and
- Assessment of operational practice changes which would potentially reduce hydrocarbon emissions.

The information generated through this program will be used by EPA to prepare control techniques guidelines documents to assist states in revising their ambient air oxidant implementation plans and to assess the need to prepare new source performance standards.

2.2 Scope

To successfully meet the above stated objectives, a five task program was devised. The tasks are briefly outlined below.

Task 1, Marine Transportation Statistics: Provision of statistics concerning current marine transportation patterns for crude oil and gasoline by geographic region.

Task 2, Growth Projections: Quantification of the amount of growth or change that is expected to take place in marine transportation activities over the next ten years.

Task 3, Operational Control Techniques: Identification of operating procedures (rather than equipment intensive technologies like vapor recovery or incineration) that could be utilized to minimize hydrocarbon emissions at or near terminals by vessels loading and unloading gasoline and crude oil.

Task 4, Effectiveness of Operational Control Techniques: Estimation of the emission levels and reductions that can be achieved with the operating procedures identified in Task 3, using existing data and engineering judgment.

Task 5, National and Regional Emissions: Preparation of estimates of the emissions from marine transfer operations for a typical terminal on a national and regional basis from existing data and engineering calculations.

2.3 Approach

To accomplish the project objectives, Radian established contacts with the petroleum industry, the marine industry, trade associations, and government agencies. These contacts are summarized in Appendix A, Industry Contacts. Initially Radian met with the U.S. Coast Guard and representatives of several different oil companies and marine transportation corporations. When these sources were unable to provide adequate information, an intensive effort was made to retrieve statistics from trade associations and government agencies. These latter two sources provided the foundation for the marine transportation pattern statistics reported in this study. Radian was also able to utilize in-house experience and data in projecting transportation patterns for the next decade and in estimating the potential reduction of hydrocarbon emissions by operational practice changes.

3.0 BACKGROUND INFORMATION

Petroleum refining operations in the U.S. are centralized in a few major refining regions. These regions are in or near the major oil producing areas. Much of the consumption of petroleum products lies outside these production and refining regions. In addition, the overall domestic demand for crude and petroleum products has far outpaced U.S. production and refining capabilities. U.S. reliance on imports is increasing with each year. Both circumstances have resulted in a complex transportation network for crude and petroleum products of which the marine industry is a major part.

3.1 Marine Transportation in the Petroleum Refining Industry

According to one source, more petroleum is carried by water than any other commodity.[1] Although the water carriers' share of the domestic market has declined with respect to other modes of transportation, the total volume has steadily increased. With the exception of two crude oil pipelines from Canada, virtually all imports of crude oil and finished petroleum products are handled by water carriers.

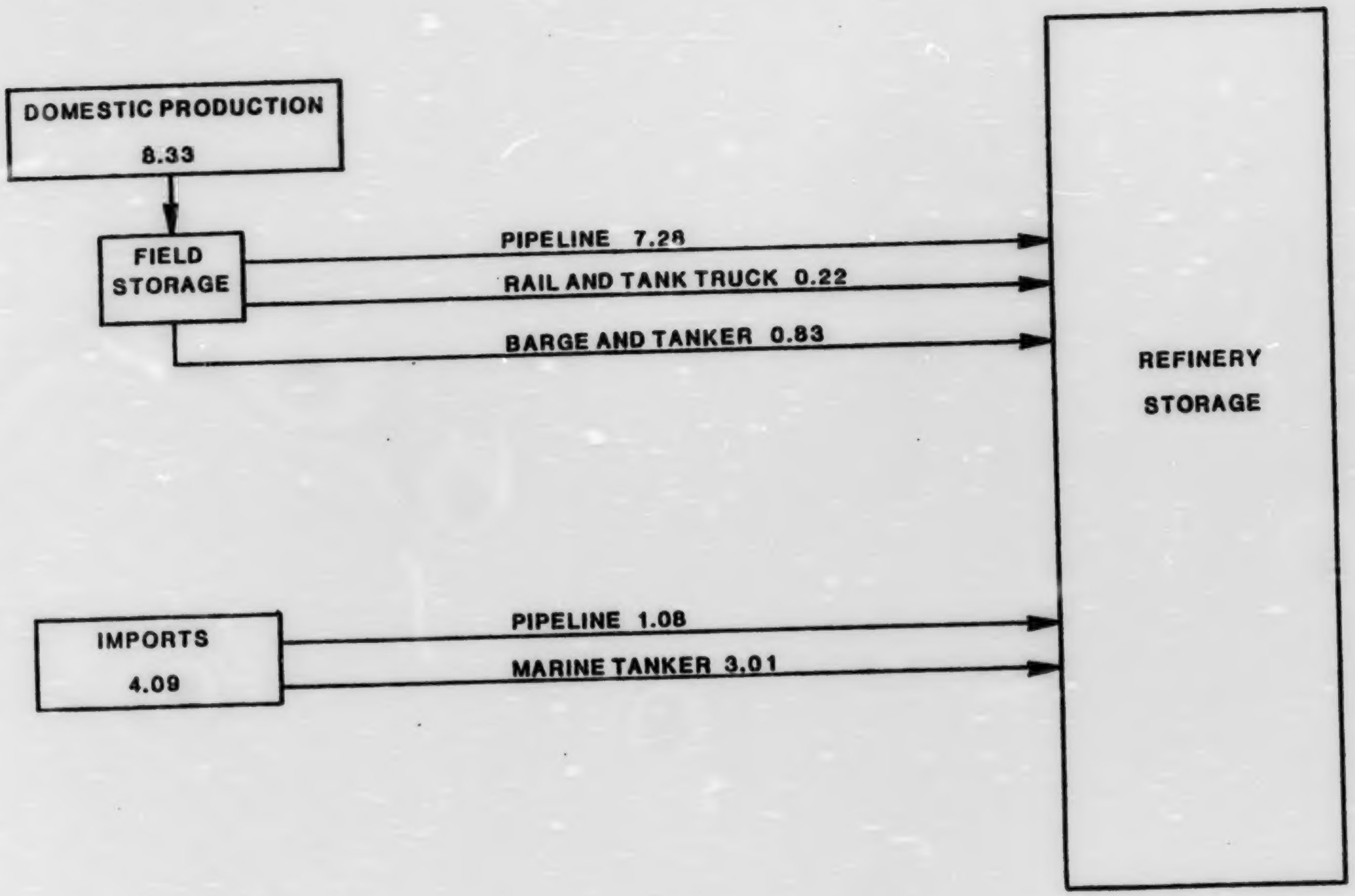
For the purposes of this report the marine transportation network was divided into five geographic areas: East Coast, Gulf Coast, West Coast (including Alaska and Hawaii), Great Lakes, and Inland Waterways. There is only a small amount of petroleum transportation on the Great Lakes. The 1975 total of 86.6 million barrels represents a decline of 9 percent from the previous year and reflects a long term trend.[1] This steady decrease in water carrier service can be attributed to the competition of pipelines which can be operated when tankers and barges are ice-bound. Due to the incompleteness of Great Lakes statistics, many of the statistics compiled for this study consider the Great Lakes and Inland Waterways as a single region.

In 1975 the United States flag fleet was ranked eighth (in total tanker tonnage) in the world.[2] More recent statistics show that in 1977 there were a total of 397 U.S. flag tankers; oil companies owned and operated 75 (19%) with the remaining 322 (81%) being operated by leasing companies, independent refiners, terminal operators, and for-hire carriers. These figures do not reflect tankers owned by foreign affiliates of U.S. oil companies.

In 1977 a total of 3,053 petroleum tank barges were operating on the nation's inland waterways and along the coasts. Oil companies owned 373 barges and leased another 66, for a total capacity of 8.43 million barrels.

3.1.1 Marine Transportation of Crude Oil

In 1975 water carriers accounted for 10 percent of the domestic receipts and 74 percent of the foreign receipts of crude oil at U.S. refinery centers. Overall, marine transportation accounted for 31 percent of crude oil receipts at refineries. While the amount of domestic crude handled by marine transportation is declining, the arrival of North Slope crude at the Valdez terminal during the summer of 1977 will begin to reverse this trend. In addition, the quantities of foreign crude oil being shipped to U.S. refinery centers, particularly on the East Coast, have increased significantly. The water carriers' share of crude oil transport should steadily increase in the future. Figure 3.1-1 illustrates the various crude oil transportation patterns.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RAIL AND TANK TRUCK 0.22
BARGE AND TANKER 0.83
REFINERY STORAGE
IMPORTS
4.09
PIPELINE 1.08
MARINE TANKER 3.01

FIGURE 3.1-1 TRANSPORTATION OF CRUDE OIL, 1975
(RATES IN MILLIONS OF BARRELS PER DAY)

SOURCE: MINERAL INDUSTRY SURVEYS, ANNUAL PETROLEUM STATEMENT (Reference 3)

3.1.2 Marine Transportation of Gasoline

Statistics for 1975 show that 9.5 percent of domestic gasoline shipments and nearly all (97.8 percent) of imported gasoline shipments were made by water carriers. Overall, marine transportation accounted for 12 percent of the gasoline transported to U.S. bulk terminals.[2] This percentage is considerably less than the national domestic average for all petroleum products, in which ships and barges accounted for 15 percent and 30 percent, respectively, as the primary means of transportation to bulk terminals.[4] The various methods of transporting gasoline from refinery storage to bulk terminals are shown in Figure 3.1-2.

The major traffic pattern for flow of gasoline in the United States is from refineries along the coasts of Texas and Louisiana to high population centers along the East Coast. A large portion of the gasoline is carried by the Colonial Pipeline which originates in the Houston area and terminates at New York City. Since there are relatively few pipelines to the six-state New England area, this region relies predominantly on water carriers for gasoline supply with some support from tank cars and trucks. Therefore, the substantial coastal transportation networks should continue to handle large volumes of gasoline. The traffic should increase in the foreseeable future.

3.1.3 Economics of Marine Transportation

Transportation of crude and gasoline by tanker is by far the cheapest means of conveying these cargoes. The average cost ranges from about $0.15 to $0.40 per thousand barrel miles. Pipelines represent the nearest competition at a cost of from $0.30 to $1.20 per thousand barrel miles and barges are a close third at $0.40 to $1.50 per thousand barrel miles.

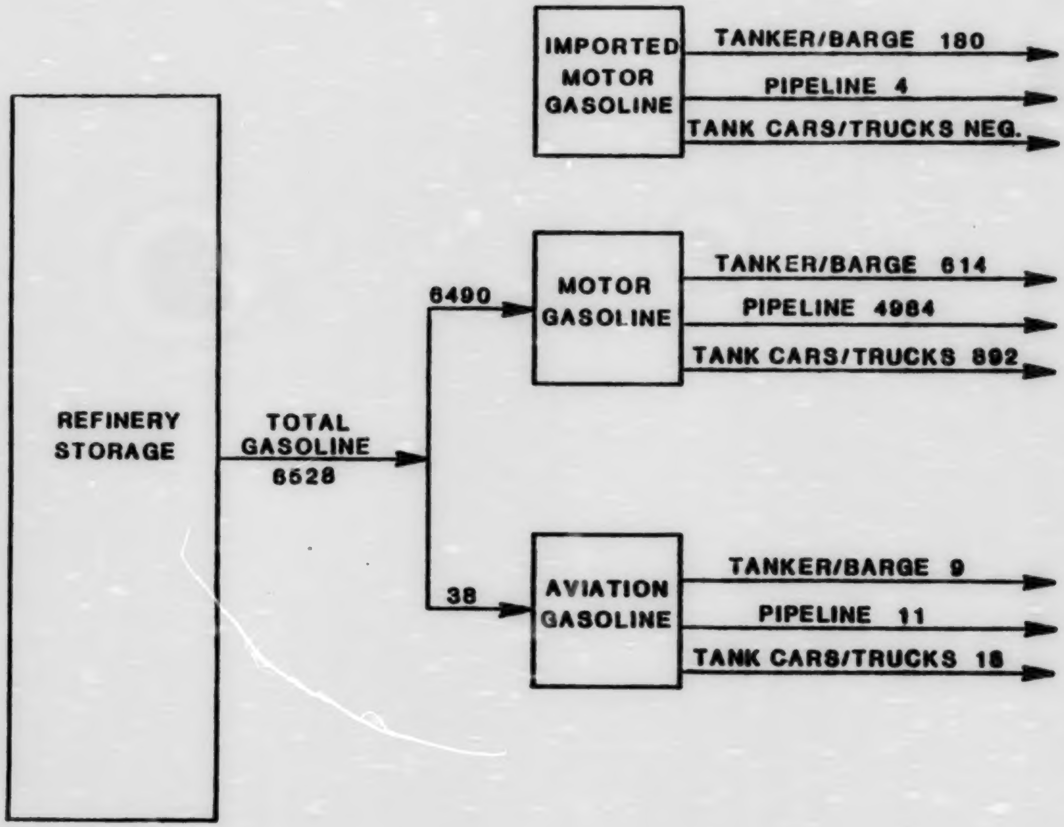

REFINERY STORAGE
TOTAL GASOLINE 6528
6490
38
IMPORTED MOTOR GASOLINE
TANKER/BARGE 180
PIPELINE 4
TANK CARS/TRUCKS NEG.
MOTOR GASOLINE
TANKER/BARGE 614
PIPELINE 4984
TANK CARS/TRUCKS 892
AVIATION GASOLINE
TANKER/BARGE 9
PIPELINE 11
TANK CARS/TRUCKS 18

FIGURE 3.1-2 TRANSPORT OF GASOLINE
(RATES IN THOUSANDS OF BARRELS PER DAY, 1975)

SOURCE: MINERAL INDUSTRY SURVEYS, ANNUAL PETROLEUM STATEMENT (Reference 2)

According to the U.S. Coast Guard, the average capacity of U.S. tankers is 210,353 barrels or about 33,000 dwt. The draught of such a vessel would be approximately 34 feet. Recently, however, the increasing worldwide demand for Middle East crude oil and the economics of volume transportation have led to the construction and use of ships of 265,000 dwt. with a 67 foot draught. Table 3.1-1 shows that no U.S. receiving ports are capable of docking these very large crude carriers (VLCC's). Since Freeport in the Bahamas can accommodate vessels up to 380,000 dwt., it has become an exchange terminal where VLCC's from the Middle East can unload crude oil and smaller ships, which are able to negotiate U.S. harbors, can reload the oil for final delivery to East Coast and Gulf Coast refinery centers.

The low cost of barge transportation can be attributed primarily to the extremely large size of a unit movement and the innovative designs for floating equipment. On the calm waters of inland waterways, large numbers of barges can be lashed together to form flotillas with capacities of 80,000 to 100,000 barrels. This has enabled barge service to operate at an average of three mills per ton-mile as compared with rail and truck service costs of eleven and eighty mills per ton-mile, respectively.[1] Recently, ocean-going barges (7,500 - 35,000 dwt.) have become important factors in petroleum transportation. Powered by ocean-going tugboats, these barges have been used to lighter tankers which are too large to enter port. The petroleum liquids are then barged to nearby refineries, population centers or transhipment points.

3.2 Marine Terminal Operations

Basically two operations occur at the major marine terminal of refining centers: loading and unloading of crude

TABLE 3.1-1. ESTIMATED MAXIMUM VESSEL SIZE OF U.S. PORTS

	DWT (Current)
East Coast	
Baltimore, Md.	35,000
Boston, Mass.	60,000
Delaware River Ports	55,000
Hampton Roads, Va.	40,000
Jacksonville, Fla.	30,000
Miami, Fla.	20,000
New York, N.Y.	70,000
Port Everglades, Fla.	50,000
Portland, Maine	70,000
Savannah, Ga.	35,000
Gulf Coast	
Baton Rouge, La.	50,000
Baytown, Tex.	50,000
Beaumont, Tex.	35,000
Corpus Christi, Tex.	55,000
Freeport, Tex.	40,000
Galveston, Tex.	35,000
Houston, Tex.	35/50,000
Lake Charles, La.	50,000
Mobile, Ala.	50,000
Nederland, Tex.	50,000
New Orleans, La.	50,000
Pascagoula, Miss.	50,000
Port Arthur, Tex.	50,000
Texas City, Tex.	35,000

(Continued)

TABLE 3.1-1. ESTIMATED MAXIMUM VESSEL SIZE OF U.S. PORTS (CONTINUED)

	DWT (Current)
West Coast	
Anacortes, Wash.	120,000
Anchorage, Alaska	35,000
Ferndale, Wash.	150,000
Honolulu, Hawaii	35,000
Long Beach, Calif.	120,000
Los Angeles, Calif.	110,000
Portland, Oreg.	35,000
Richmond, Calif.	35,000
San Diego, Calif.	35,000
San Francisco, Calif.	55,000
Tacoma, Wash.	150,000
Valdez, Alaska	150,000

Sources: References 5, 6

oil and petroleum products. In some instances the same dock area can not be used for both operations. In addition, petroleum products are unloaded at bulk terminals that serve as distribution centers for wide marketing areas.

Very little crude oil is loaded at one refining center for transport to another. The small amount that does undergo such transfer is almost exclusively loaded in the Texas-Louisiana coastal area for shipment to refining centers along the Delaware River and lower New York Bay. In 1974 tankers delivered about 60 million barrels by this route.[1] Crude oil loading operations are also carried out at offshore production platforms and in the swamps of Louisiana at "mudhole" wells. The crude is then unloaded at nearby coastal refineries for processing.

In the summer of 1977 the United States will have its first major oil loading port when Valdez, Alaska initiates operations for North Slope crude. Three berths designed to handle tankers up to 150,000 dwt. will be equipped with four 16-in. loading arms. A smaller fourth berth will be for 120,000 dwt. tankers and will have four 12-in. loading arms. All four berths will have a 42-in. ballast line which will connect to a 1.33 million b/d ballast-water treatment facility. Estimated tanker loading time will be 22 to 30 hours. Future plans provide for a fifth berth and modifications to increase three original berths to accommodate 250,000 dwt. tankers. Initial flow is expected to be 600,000 b/d and to increase to 1.2 million b/d by the end of the year.[6]

3.2.1 Unloading Operations

After the ship is docked at the terminal where it will discharge its load, dock and ship personnel connect the shore and ship manifolds using cargo hoses or hydraulic arms. Then, the ship's main cargo pumps are used to discharge the cargo. These pumps vary in number and capacity for different tankers. The tanks are unloaded from the bottom, just as they are loaded. During unloading the P/V valves are manually opened and the ullage caps are opened.

Once the main cargo pumps have removed all the cargo possible, they are switched off. The smaller stripper pumps and lines are used to remove the remaining cargo from each tank. This procedure is called stripping. Each cargo tank's strippings are pumped to a designated cargo tank usually located aft. When all the tanks have been stripped, the main cargo pump for the tank holding the strippings is used to pump them ashore. This completes the unloading operation.

Before the tanker departs, however, it must take on some ballast to make it seaworthy. A ballast diagram drawn by one of the ship's officers determines which tanks will be ballasted. The sea valves to these tanks are opened allowing water to flow in. The displaced vapors are vented through the ullage cap and P/V valve which are still open.

Ships reportedly may ballast anywhere from 20 to 40 percent of their cargo capacity before leaving the dock, depending upon the ship officer's orders. Should weather conditions dictate it, more ballast may be taken on while the ship is at sea. The level of ballast in the tanks is usually fairly high. This minimizes the danger of the ship's developing severe rolling in bad weather due to the sloshing of the ballast in its tanks.

After ballasting is completed, the ullage caps are closed; the P/V valves are returned to their normal position; and the ship readies for departure.

There are relatively few differences between the unloading of crude oil and gasoline. Perhaps the greatest difference is the extra care which must be taken in connecting discharge hoses in order to avoid faulty hose alignment and subsequent gasoline grade contamination.

3.2.2 Gasoline Loading of Tankers

As the ship nears the refinery dock, it discharges the clean ballast water into the channel. With the help of several tugs it is piloted into position at the dock and made fast to the shore moorings with its heavy docking lines. Crew members and shore personnel next connect the ship's slop line to the shore slop line. Any oily ballast water onboard the ship is pumped through this line to the refinery for treatment before it can be discharged. Depending upon the amount of dirty ballast on board, this operation may take 10 or more hours to complete. Once the deballasting of the cargo tanks is complete, they are stripped, using small stripper lines located in the bottom of each tank. This operation removes the small amount of ballast the larger cargo pumping lines cannot remove.

After the deballasting is finished, cargo loading hoses are connected to the shore lines in preparation for receiving product. A specific loading pattern and loading sequence for the tanks is determined by the ship's officers. Improper loading patterns can cause the vessel to be improperly trimmed or even rupture if the stresses are sufficiently high. Flexible hoses are attached to the proper shore and ship flanges. After each tank has been visually inspected and approved, the deck officer advises the shoreside operators that the ship is ready to accept cargo. Before the shoreside loading pump is turned on, the product is usually allowed to gravity feed from the shoreside tank through the loading line and into the vessel's tank (or tanks). This is done to insure that flow has been established and that the cargo lineup is correct.

Once verification has been made that the lineup to a tank is correct, the crew advises the shoreside operators to turn on the loading pump. The displaced vapors are usually vented through the ullage cap located atop the cargo tank hatch. The vapors may be vented out the P/V valve to the stack if the ullage cap is closed. Each cargo tank P/V valve is manually lifted off its seat during the loading operation to insure that a faulty valve does not cause overpressurization of the tank. Periodic checks of the ullage gauges of the tanks are made as they fill with gasoline.

Typically, several tanks are being filled at once. Loading may be interrupted from time to time to correct trim on the vessel. For those situations in which three tanks across are being filled simultaneously with the same grade of gasoline, a special loading sequence is usually followed. The levels of the center tank and the two wing tanks are allowed to reach an ullage of perhaps 15 to 20 feet. Then the flow to the center tank is shut off and the two wing tanks are brought up, one level slightly behind the other. Usually two to four members of the crew are responsible for bringing the product level up to the final ullage. This procedure is called "topping off". It is accomplished with calibrated sticks about five to six feet long. These sticks are inserted like dipsticks into the tank from the ullage cap and the ullage read directly from the stick. When the product reaches the desired final ullage, the flow to that tank is shut off. Then, the other wing tank is topped off. Following this, the flow is resumed into the center tank until it is topped off.

This procedure is used for safety reasons. The wing tanks have a smaller volume than the center tank. Should any problem occur during the topping off of a wing tank, flow can be quickly and easily diverted into the center tank which has plenty of available space. Another reason for this sequence is that it is more difficult to top off three tanks in a short time than it is to first finish the two wing tanks and then the center.

For the topping off of the final cargo tank loaded with gasoline, the crew keeps in touch with the shoreside operators with walkie-talkies. A crew member notifies the operators the instant they should shut off the loading pumps of that grade of gasoline to complete the product transfer. Then the loading lines are disconnected; the ullage caps are sealed shut; the P/V valves are returned to their operating position; and the crew readies the ship for departure.

The loading of crude oil on tankers involves techniques and equipment which are very similar to those previously described for the loading of gasoline.

3.2.3 Gasoline Loading of Barges

Barges differ from ships in that they do not take on ballast after unloading. Empty barges are returned by tugboat to the terminal where they are to load their next product. Usually no cleaning is performed on the cargo tanks because barges lack cleaning facilities and convenient disposal methods for the cleanings. For these reasons they remain in a single product service until the barge is sent to drydock for repairs. While in dry dock the barge tanks are cleaned by removing all hydrocarbon vapors so that regularly scheduled maintenance on its equipment can be performed. Following this work, the barge would be free to switch cargo service.

For loading gasoline or crude oil the barge is moved into position at the marine dock by a tugboat and then secured with mooring ropes. Cargo hoses or hydraulic arms, if they are available, are attached to the barge's cargo loading header and to the shore manifold.

The barge is filled in much the same manner as a ship. Usually, however, only one person is available to monitor loading operations on the barge. Barge tanks require more frequent monitoring because the loading rate is generally higher relative to tank size as compared to tankers. Observations on the product level are made by direct sighting through an ullage cap. Topping off is completed in the same manner on barges as on ships.

The loading of crude oil on barges involves techniques and equipment which are very similar to those just described for the loading of gasoline.

3.3 Characterization of Hydrocarbon Emissions

Hydrocarbon emissions are generated at marine terminals when volatile hydrocarbon products are either loaded onto or unloaded from ships and barges. Loading emissions result from the displacement to the atmosphere of hydrocarbon vapors by products being loaded into the vessel tanks. Unloading emissions are hydrocarbon vapors displaced during ballasting operations at the unloading dock following the delivery of a volatile hydrocarbon liquid cargo such as crude oil or gasoline.

Loading emissions can be separated into the arrival component and the generated component. The arrival component consists of hydrocarbon vapors left in the empty cargo tanks from the previous cargo. The generated component consists of hydrocarbon vapors generated in the cargo tanks as hydrocarbon liquids are being loaded.

Unloading emissions occur when an empty marine vessel not equipped with segregated ballast takes on ballast water before leaving port. Unloading emissions apply only to tankers and ocean barges, since inland waterway barges do not take on ballast water. During the unloading of a volatile hydrocarbon liquid, air drawn into the emptying tank absorbs hydrocarbons evaporating from the liquid surface. Before sailing, the empty marine vessel will fill several cargo tanks with ballast water to maintain trim and stability. As the ballast water enters the cargo tanks it generates "unloading emissions" by displacing residual hydrocarbon vapors to the atmosphere.

4.0 MARINE TRANSPORTATION PATTERNS

The movements of crude oil and gasoline by ships and barges have established worldwide transportation patterns from production regions to refining centers to consumption areas. Until the past decade, the United States has been at the center of all three processes: production, refining and consumption. Recently, however, U.S. demand for crude oil and finished petroleum products has far outpaced the domestic capacity for production and refining. The result has been steady increase in imports to meet demand. Consequently, marine transportation patterns for crude oil and gasoline have changed. This section contains a discussion of the present network of marine transportation patterns for crude oil and gasoline and will project how these patterns might be altered in the next decade.

4.1 Crude Oil Movements

In 1975 almost 31 percent of the crude oil input to refineries was received by ship or barge. This figure can be expected to increase significantly in the immediate future. Although marine transportation accounted for only 10 percent of the domestic crude oil shipments, the transfer of North Slope crude from Valdez to ports on the Pacific Coast and Gulf Coast should more than double the amount presently shipped by tanker. In addition, the decline in Canadian pipeline imports will almost certainly be offset by increasing tanker imports from the Middle East. Therefore, marine transportation is expected to assume an even more important role in the future movements of crude oil from production regions to U.S. refining centers.

Historically, the four major refining centers in the U.S. have enjoyed a relatively stable supply of crude oil.

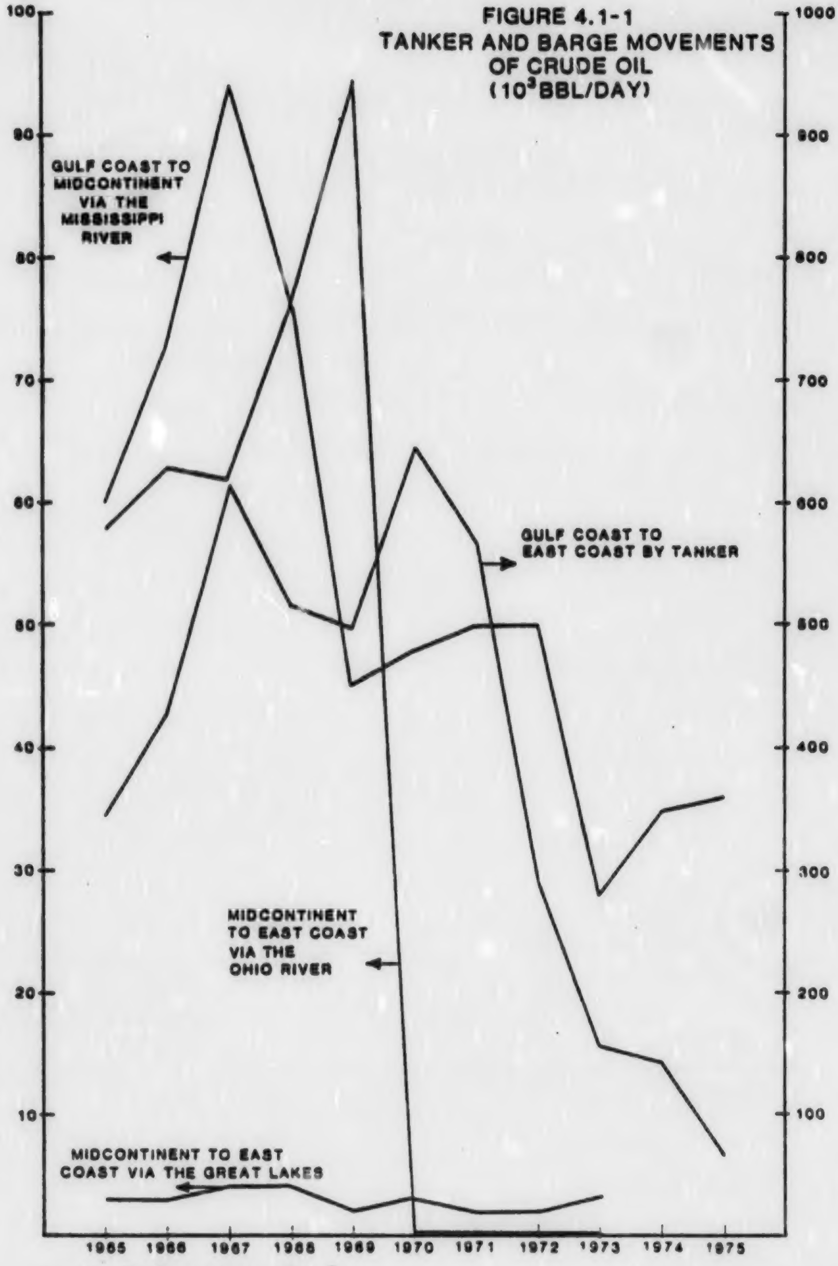
The East Coast has depended almost exclusively on tanker deliveries of imported crude, supplemented by minor tanker receipts from the Gulf Coast. Midcontinent refineries, on the other hand, have relied heavily on pipeline transmission of oil from Texas, Louisiana, and Canada with only negligible amounts supplied by inland river barge. Refining centers on the Gulf Coast and West Coast have normally received both domestic crude by pipeline and imported crude by tanker. The recent history of the marine transportation patterns is graphically illustrated in Figure 4.1-1. By 1975, however, decreasing domestic oil production and increasing petroleum products demand had already resulted in altered crude oil transportation patterns.

The most significant change has been in crude oil supply to Midcontinent refineries, which have relied historically on imported Canadian crude. Table 4.1-1 illustrates the dependence of this area on Canadian crude and indicates the dilemma facing refineries as this source declines. In 1976 Canadian imports were averaging 460,000 bpd. In 1978 Canadian imports are expected to be down 64 percent, and by 1982 they are expected to be phased out altogether.[9]

TABLE 4.1-1. PERCENTAGE OF CRUDE OIL TO WEST AND MIDWEST REFINERIES SUPPLIED BY CANADIAN OIL

State	Percent of Crude Supplied by Canada
Minnesota	87%
Wisconsin	87%
Washington	57%
Montana	30%
Michigan	21%
North Dakota	18%

Source: Reference 9



SOURCE: References 3, 8

For the Midcontinent refining center the short term answer appears to be importing Middle East crude via Mississippi River barge. In 1976 one Minnesota refiner was already barging 25,000 bpd with plans to double that amount by 1977. If other Midcontinent refiners follow suit, crude oil shipments by barges on inland waterways will increase to its highest activity since 1967. This could also become a long term solution if excess North Slope crude is brought to the Gulf Coast via the Panama Canal. Estimated Transportation cost for moving North Slope crude to either the Gulf Coast or East Coast is $1.75 per barrel. The cost increases to $3.34 if the final destination is Chicago.[9]

Another alternative for supplying Midcontinent refineries with North Slope crude hinges on the construction of any of three proposed pipelines. The Kitimat line would connect Kitimat, British Columbia with other Canadian-U.S. pipeline networks and would be capable of moving 300,000 bpd initially. The Northern Tier Pipeline would run from Port Angeles, Washington to Clearbrook, Minnesota and have a capacity of 600,000 bpd. The Sohio Pipeline could handle 500,000 bpd and would run from Long Beach, California to the pipeline network in Midland, Texas.

All three proposed pipelines have encountered economic and environmental problems. For instance, the California Air Resources Board estimates that a 70,000 bpd terminal at Long Beach would have hydrocarbon emissions of 40 tons/day. Sohio, however, has calculated emissions to be only 1 ton/day and plans to reduce emissions, possibly by using segregated-ballast tankers.[9] Sohio is also attempting to secure agreements from local dry-cleaning establishments and a glass manufacturer, which would require these industries to reduce their hydrocarbon emissions in order to satisfy the EPA emissions offset policy.[10]

Should Midcontinent refineries depend on excess North Slope crude, the long range benefit is questionable. While it is true that West Coast refineries cannot presently process all the sour North Slope crude (see Table 4.102), the estimated surplus of 762,000 bpd is expected to disappear by the mid-1980's.

TABLE 4.1-2. WEST COAST DESTINATIONS OF NORTH SLOPE CRUDE

Company	Location	Sour Crude Capacity (bpd)
ARCO	Cherry Point, Wash.	96,000
	Carson City, Calif.	100,000
Exxon	Benicia, Calif.	45,000
Gulf	Sante Fe Springs, Calif.	197,000
Mobil	Torrance, Calif.	
	Ferndale, Wash.	
Shell	Martinez, Calif.	
	Wilmington, Calif.	
	Anacortes, Wash.	
Socal	El Segundo, Calif.	
	Richmond, Calif.	
Tosco	Martinez, Calif.	
Union	Los Angeles, Calif.	
	San Francisco, Calif.	
		438,000

Source: Reference 11

Therefore Midcontinent refineries may have to rely on the future production of major discoveries in Alaska and/or California and West Coast imports to prove the economics of any proposed pipeline. At any rate, some form of crude oil imports will play a significant role in the future supply of Midcontinent refineries.

In the past ten years (1965-1975), imports of crude oil to the United States have more than tripled. Imported crude accounted for 33 percent of the total U.S. refinery receipts in 1975. Table 4.1-3 compares the steady shift in import sources from Canada and South America to the Middle East and Africa.

TABLE 4.1-3. U.S. IMPORTS OF CRUDE OIL

Source	% Provided by Source	
	1965	1975
Canada	23.8	14.6
Middle East	24.8	27.3
Africa	5.4	32.6
South America	38.3	13.9
Other	7.7	11.6
OPEC	69.9	78.2

Sources: References 3,8

Since Canadian imports are expected to cease altogether by 1982, essentially all foreign crude will arrive in the U.S. by tanker. Import activity is expected to remain high and continue to increase, though perhaps at a slower rate. At full production, the North Slope crude will temporarily postpone the inevitable decline in domestic crude oil production, but demand on the East Coast and probably on the Gulf Coast, due to the needs of

Midcontinent refiners, should continue to increase. Table 4.1-4 presents the origin and destination of approximately 99.4 percent of the U.S. crude oil imports in 1975.

In order to provide the most current information on marine transportation of domestic and imported crude oil, Table 4.1-5 was organized according to the four major geographic areas.

4.2 Gasoline Movements

Determining accurate gasoline movements by marine transportation methods is extremely difficult since most statistical data is presented in the more general form of "petroleum products". What reliable data that is available is summarized in Table 4.2-1. An effort to further reduce this data by using estimates from maps prepared by the U.S. Geological Survey on petroleum products movement has yielded the results organized in Table 4.2-2.

A study of the 1974 gasoline statistics given in Table 4.2-2 shows that the bulk of gasoline movement by water carrier is from the Gulf Coast to the East Coast, in spite of the Colonial Pipeline which runs from Houston, Texas to New York City and has a daily capacity of 960,000 barrels. Significant amounts of gasoline are also distributed along the Great Lakes and Inland Waterways. This amount could increase substantially if the unavailability of crude oil prevents refinery growth in the Midcontinent region from keeping pace with the increasing demand for petroleum products in that area. The marine transport of gasoline from the Gulf Coast to the West Coast has always been minimal and could cease altogether with the arrival of North Slope crude.

TABLE 4.1-4. 1975 CRUDE OIL IMPORTS (THOUSANDS OF BARRELS)

		Destination				
Origin	Total	East Coast	Great Lakes, Inland Waterway	Gulf Coast	West Coast	Puerto Rico
Africa						
Nigeria	275,015	88,005 (32)*		178,760 (65)	5,500 (2)	2,750 (1)
Algeria	98,428	44,293 (45)		51,183 (52)	984 (1)	1,969 (2)
Libya	83,064	20,766 (25)		57,314 (69)	3,323 (4)	1,661 (2)
Angola	28,946	19,104 (66)		6,947 (24)		2,895 (10)
Gabon	11,965	9,213 (77)		598 (5)		2,154 (18)
Middle East						
Saudia Arabia	258,622	82,759 (32)		134,483 (52)	38,793 (15)	2,586 (1)
Iran	112,861	38,373 (34)		24,829 (22)	38,373 (34)	11,286 (10)
Arab Emirates	43,454	5,649 (13)		23,900 (55)	13,036 (30)	869 (2)
Kuwait	1,444	1,097 (76)			347 (24)	
Qatar	6,657			4,061 (61)	2,596 (39)	
North America						
Canada	219,175		162,190 (74)		56,986 (26)	
Mexico	28,198	1,692 (6)		23,968 (85)		2,538 (9)
South America						
Venezuela	182,558	96,756 (53)		29,209 (16)	18,256 (10)	38,337 (21)
Ecuador	24,914			1,993 (8)	18,686 (75)	4,235 (17)
Trinidad	42,956	6,873 (16)		35,224 (82)		859 (2)
Asia						
Indonesia	138,270	11,062 (8)		16,592 (12)	110,616 (80)	
Europe						
Norway	4,552	774 (17)		3,778 (83)		

*Indicates % of total imported from that country

Source: Reference 3

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TABLE 4.1-5. 1975 REFINERY RECEIPTS OF CRUDE OIL BY TANKERS AND BARGES (THOUSANDS OF BARRELS)

Region & State	Crude Oil Input to Refineries	Refinery Receipts (Domestic) Intrastate Tankers & Barges	Refinery Receipts (Domestic) Interstate Tankers & Barges	Refinery Receipts (Foreign) Tankers & Barges	% By Marine Trans.
East Coast					
Delaware, Maryland	49,925	--	5,153	44,497	99.4
Fla., Ga., Virginia	23,278	--	31	21,983	94.6
New Jersey, Rhode Is.	189,233	--	11,954	178,121	100.4
New York, New Hamp.	31,238	--	--	1,855	5.9
Penn. (East)	192,411	--	14,233	171,935	96.8
	486,085	--	31,371	418,391	92.5
Gulf Coast					
Texas	1,210,366	17,220	64,015	303,361	31.8
Louisiana	549,790	80,169	8,112	89,159	32.3
Mississippi	98,253	--	--	38,600	39.3
Alabama	13,169	661	459	671	13.6
	1,871,578	98,050	72,586	431,791	32.2
Great Lakes & Inland Waterways					
Arkansas	19,211	--	--	--	--
Oklahoma	167,132	--	--	--	--
Missouri, Nebraska	33,833	--	--	--	--
Kansas	141,119	--	--	--	--
Kent., Tenn.	70,423	--	14,147	159	20.3
Illinois	357,870	--	--	--	--
Minn., Wisconsin	69,201	--	--	--	--
Indiana	163,277	--	2,515	--	1.5
Ohio (East)	20,897	--	--	--	--
(West)	162,686	--	--	--	--
Michigan	41,318	--	--	--	--
Penn (West)	21,998	--	1,563	--	7.1
West Virginia	5,720	--	1,187	--	20.8
	1,274,685	--	19,412	159	1.5
Pacific Coast					
California	562,462	36,807	43,084	191,190	48.2
Washington	105,792	--	3,683	42.754	43.9
Ore., Alas., Hawaii	38,594	--	32	16.688	43.3
	706,848	36,807	46,799	250,632	47.3
	4,339,196	134,857	170,168	1,100,973	32.4

Source: Reference 3

TABLE 4.2-1. TANKER AND BARGE MOVEMENTS OF GASOLINE IN 1974 (THOUSANDS OF BARRELS)

Origin	Destination	Cargo	
		Motor Gasoline	Aviation Gasoline
Gulf Coast	New England	24,084	357
	Central Atlantic	51,644	767
	Lower Atlantic	101,180	1,856
	Midcontinent	27,357	533
	West Coast	1,392	--
Midcontinent	East Coast		
	Via Great Lakes	1,054	--
	Via Ohio River	4,834	--

Source: Reference 3

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TABLE 4.2-2. 1974 GASOLINE STATISTICS (THOUSANDS OF BARRELS)

Region & State	Gasoline Production	% of Total Petro. Prod. Produced	Gasoline Consumption	% of Total Petro. Prod. Consumed	Gasoline Surplus or (Deficit)	Receipts & (Shipments) by Tanker and Barge	
						Domestic	Foreign
East Coast							
Maine	--	--	12,382	29.6	(12,382)	1,268	7,446
New Hampshire	--	--	9,299	38.6	(9,299)	1,268	5,381
Vermont	--	--	5,603	47.1	(5,603)	2,803	1,376
Massachusetts	--	--	54,689	28.4	(54,689)	12,676	28,149
Rhode Island	885	40.4	8,851	35.3	(7,966)	1,268	4,488
Connecticut	--	--	31,602	33.0	(31,602)	6,338	16,927
New York	13,864	40.4	142,806	32.2	(128,942)	20,270	19,740
New Jersey	90,024	40.8	75,588	34.6	14,436		
Penn. (East)	100,300	35.5	102,858	44.3	(2,558)	18,015	8,400
Delaware	22,324	43.6	7,059	26.7	15,265	(10,000)	--
Maryland	4,252	43.5	42,606	39.0	(38,354)	36,412	7,380
Virginia	8,139	40.7	58,130	42.4	(49,991)		
North Carolina	--	--	67,150	58.3	(67,150)	7,367	1,344
South Carolina	--	--	34,682	56.7	(34,682)	7,367	1,260
Georgia	2,831	40.7	65,229	55.6	(62,398)	10,314	1,260
Florida	826	40.7	100,124	43.8	(99,298)	76,131	6,720
	243,445	38.7	818,658	39.3	(575,213)	191,497	110,371
Gulf Coast							
Texas	609,847	41.7	169,030	51.7	440,817	(123,579)	2,569
Louisiana	281,788	44.0	41,818	39.3	239,970	(83,499)	2,569
Mississippi	49,911	31.4	28,461	45.4	21,450	(2,092)	1,285
Alabama	528	4.4	44,349	56.5	(43,821)	--	428
	942,074	41.4	283,658	49.5	658,416	(209,170)	6,381
Great Lakes & Inland Waterways							
Arkansas	7,443	35.6	27,433	44.3	(19,990)	2,418	--
Oklahoma	99,384	43.5	39,393	61.3	56,691	--	--
Missouri	15,510	43.3	62,586	59.4	(47,436)	5,736	--
Tennessee	6,131	43.6	51,948	65.9	(45,817)	5,540	--
Kentucky	23,066	43.6	39,919	63.9	(16,853)	2,038	--
Indiana	80,022	43.3	65,216	47.9	14,806	(8,400)	--
Illinois	216,355	52.9	119,637	48.9	96,718		500
Minnesota	32,604	52.6	48,431	50.3	(15,327)	1,914	--
Wisconsin	7,157	52.6	51,084	55.7	(43,927)	5,354	--
Iowa	--	--	39,215	57.5	(39,215)	4,742	--
Ohio	117,622	48.0	119,193	63.9	(1,571)	190	840
Michigan	19,543	40.3	108,694	58.5	(89,151)	--	42
Penn. (West)	11,466	35.5	11,758	44.3	(292)	2,417	--
West Virginia	1,394	24.1	18,248	65.3	(16,854)	2,417	--
	637,537	47.1	803,255	55.9	(165,718)	24,366	1,382
West Coast							
California	260,452	33.2	235,428	52.9	25,024	1,392	163
Oregon & Idaho	486	14.7	39,178	51.3	(38,692)	420	--
Washington	60,086	50.0	39,684	51.7	20,402	--	--
Alaska	2,370	14.7	3,883	20.6	(1,513)	--	1,513
Hawaii	3,039	14.7	6,615	21.6	(3,576)	2,650	926
	326,433	34.5	324,788	50.1	1,645	4,462	2,602
	2,149,489*	46.1	2,230,359**	47.0	(80,870)	238,725 (227,570)	121,206

* Represents 93% of the National Total

**Represents 92% of the National Total

Sources: References 1,3

Of increasing significance is the growing amount of imported petroleum products being received at U.S. ports, especially along the East Coast. In 1974 the United States imported a total of 885 million barrels of finished petroleum products, 85 percent of which was received at the East Coast.[3] A major factor in the increasing East Coast dependence on imported products has been the economic situation fostered by federal legislation. The Jones Act requires that domestic marine trade be handled by U.S. shipping. Since the costs of U.S. tankers have been higher than those of foreign flag ships, imported petroleum products have been cheaper at their East Coast destination than domestic products. Table 4.2-3 summarizes the imported petroleum products during 1974. Gasoline accounted for 8.4 percent of the total finished petroleum products imported that year.[3]

Transportation of domestic petroleum products from refinery centers to consumption areas is actually a two step process. The first step is transfer from loading refinery bulk terminals to receiving marketing bulk terminals. In 1975 approximately 50 percent of the domestic petroleum products was transferred by pipeline. Still another 45 percent was transferred by water carriers, with ships and barges accounting for 15 percent and 30 percent, respectively (1974 Inland Waterborne Commerce statistics). The remaining 5 percent was transferred by trucks or tank cars. Approximately 9.5 percent of the gasoline leaving refineries was transported by tanker or barge.

The second step is the transfer of petroleum products from marketing bulk terminals either directly to the consumer or indirectly to the consumer via smaller bulk stations. Almost all of the petroleum products reach the consumer and bulk station by tank truck. Less than 1 percent of the petroleum products transferred in this second step are transferred by water carrier.

TABLE 4.2-3. 1974 IMPORTS OF PETROLEUM PRODUCTS (THOUSANDS OF BARRELS)

Region and Port	Region of Origin								
	Africa	Asia	Australia	Canada	Caribbean	Cent. Am.	Europe	Middle East	South Am.
East Coast									
Portland, Maine					7,100	100	12,000	700	
Boston, Mass.	1,500			1,700	36,600	200	10,600	200	13,400
Providence, R.I.				1,000	2,200	200	3,700	200	3,900
New Haven, Conn.	300			13,000	13,000		43,900	500	6,000
New York, N.Y.	6,900		300	3,400	107,200	500	27,600	1,900	59,800
Philadelphia, Penn.	4,800	100		6,200	22,900	200	10,600	900	25,100
Baltimore, Md. & Norfolk, Va.	200		200	600	33,800	400	2,100		49,000
Wilmington, N. Car.					3,400	11,600	200	100	500
Charleston, S. Car.					3,300	200	200	200	8,500
Savannah, Ga.					5,100	100	600		4,100
Miami, Fla.	100				13,000				9,400
Tampa, Fla.					25,800	100	800		21,300
	13,800	100	500	25,900	273,400	13,600	112,300	4,700	201,000
Gulf Coast									
Mobile, Ala.					7,300	100		300	1,200
New Orleans, La.	400	200			6,200		2,900	1,300	4,100
Port Arthur, Tx.					2,200	200	1,600	600	700
Houston-Galveston, Tx.		1,100		100	3,000		8,800	1,900	15,200
	400	1,300		100	18,700	300	13,300	4,100	21,200
Great Lakes & Inland Waterway									
Detroit, Mich.									400
Cleveland, Ohio				5,000					
Buffalo, N.Y.				2,200					4,300
Ogdensburg, N.Y.				6,100					800
Albans, Vt.				800					
				14,100					5,500
West Coast									
San Diego, Cal.		1,100						100	
Los Angeles, Cal.		4,000		300	7,000		2,100	400	14,400
San Francisco, Cal.		600		200	800		200	900	2,700
Seattle, Wash.				400	600			100	900
Anchorage, Alaska		2,500			600			1,100	
Honolulu, Hawaii	1,200	7,000			1,100		200	4,700	
	1,200	15,200		900	10,100		2,500	7,300	18,000
	15,400	16,600	500	41,000	302,200	13,900	128,100	16,100	245,700

Source: Reference 1

4.3 Projections for Crude Oil and Gasoline Marine Transportation

This section contains the projections and methodology used to project marine transportation of crude oil and gasoline in the United States for the year 1985. Starting from two growth scenarios for petroleum product demands, projections for the expansion of refineries and the location of new refineries were generated. The transportation of crude oil and gasoline into and out of the refineries was projected in order to meet the feedstock requirements of the facilities.

4.3.1 Methodology

The methodology and assumptions used to project the volumes of crude oil and gasoline shipped to and from marine terminals in the United States are described in this section.

The initial step in the projection procedure involved adaptation of the energy scenarios developed by the FEA to describe possible futures and to demonstrate the dependency of the U.S. energy supply situation on pricing and regulatory policies. Each scenario includes projections of domestic oil production and foreign oil imports to meet a total petroleum liquids demand for 1985. Two projections were chosen as reasonable boundary conditions to possible futures for marine transportation. One projection requires the maximum shipping while the other requires the minimum shipping of crude oil by ship and barge.

The next step was projection of refinery growth based on the energy development scenarios previously cited. One scenario projected the maximum growth of refineries while the other projected the minimum growth. The refineries were taken as the central focal point of the study. Crude oil shipments are assumed unloaded at the refineries and gasoline shipments are assumed loaded there. Assumptions for expansion of existing refineries and location of new refineries were based primarily on oil company announcements of future growth plans.

Gasoline marketing networks were assumed to expand proportionally to the refinery expansions. In actuality marketing will follow population growth by region but no attempt was made to refine the projections to this level.

4.3.2 Projection Scenarios

The projections of future movements of crude oil and gasoline by marine transportation were based on FEA forecasts for petroleum demand in 1985. The demand for petroleum products was translated into expansion and growth of refineries. Changes in transportation patterns will depend on location of new refineries as well as any expansions of existing facilities.

The procedures developed do not include trend analysis, since past trends are not necessarily a good indication of the future. The picture of petroleum production and imports is changing rapidly and several announced policies have made past trends obsolete.

The movements of crude oil and gasoline by marine transportation over the next ten years (1975-1985) will depend on several factors including,

- Demand for petroleum products in the U.S.,
- Domestic oil production,
- Price structures for both foreign oil and domestic oil,

- Economics of marine transportation, and
- Marketing of Alaskan crude.

The ratio of domestic crude to foreign crude will impact marine transportation significantly, as most domestic crude is transported by pipeline, while most foreign crude is moved by tankers to the refinery.

The whole picture depends on the projections of energy supplies for the country. A widely accepted estimate of future demand for petroleum products was developed by the FEA.[12] This document considered several energy policy scenarios and generated a series of projections for foreign oil imports based on these scenarios. The two energy scenarios used to estimate future crude oil movements are:

1) $13/bbl for foreign oil, $9/bbl for domestic oil with a pessimistic outlook for supply (PESS), business as usual (BAU).
2) Domestic oil priced at $13/bbl.

Two growth projections were used to describe a range of possible refining industry responses to the projections of crude demand. The first refining growth scenario allows for the completion of all announced new refineries and refinery expansions. The second refining growth scenario assumes that conditions for establishing new refineries are very unfavorable and that no new refineries will be built. However, the second scenario does assume that a vigorous expansion effort will take place to compensate for the lack of new "grass roots" refinery capacity. This expansion is estimated at 2 percent per year or 20 percent over the 1975-1985 time period. This second refining growth scenario will force higher importation of petroleum products as opposed to crude oil imports.

These two refining growth projections bracket reasonable refining growth possibilities, *i.e.*, they represent the maximum and minimum growth scenarios. The blocking of refinery growth directly impacts the storage industry by shifting the product and crude import mix. The shift in import mix impacts most significantly the location of product storage. Distribution avenues rather than refinery locations are, thus, a more dominant consideration. Therefore, the use of two refining growth scenarios not only bracket that industry's possibilities, but also brackets growth possibilities in the petroleum storage industry.

4.3.2.1 Scenario I - Maximum Growth

Scenario I represents a maximum importation situation caused by low pricing of domestic crude, resulting in greater imports to meet projected demands. This scenario would result in the greatest quantities of crude to be moved by tankers to U.S. refining facilities. The scenario assumes $13/bbl as the price of imported oil and $9/bbl as the price of domestic oil with a pessimistic estimate of U.S. supplies. The impact of pricing domestic oil at low levels such as $8 or $9 per barrel is to make tertiary recovery techniques as well as new wells uneconomical. The total domestic supply impact could be as much as 2.5 MMB/D in reduced production compared to production levels estimated for domestic oil priced at $13/bbl. By 1985 the projections call for imports totaling 12.6 MMB/D compared to the 5.8 MMB/D level of 1975. Domestic production is assumed to decline slightly from the 1975 level of 10.0 MMB/D to 9.6 MMB/D. The total demand on petroleum liquids will grow to 22.2 MMB/D compared to the 1975 total of 15.8 MMB/D. All of the increase is assumed to be made up of imports. The total refining capacity, assuming importation of crude oil as opposed to products, should be around 22 MMB/D in 1985.

For the five year segment 1975 to 1980, industry announcements were used to allocate refinery growth to Air Quality Control Regions (AQCR's). Refinery expansion and new refinery projects require lead times sufficient for planning, engineering and construction. Therefore, new refineries announced for this time period should be well defined and firmly committed. Expansions require shorter lead times and should be considered less definite. However, expansions announced for the first several years were considered definite. Additional expansion announcements are to be expected for the latter part of this time period. The list of announced expansions and new facilities brings the U.S. crude refinery capacity to approximately the refinery capacity projected for 1980.

The period of 1980-1985 was projected using announced projects and an additional incremental expansion of the refining industry of 1 percent per year. The industry announcements used are listed in Appendix B as Uncertain, Undefined, or Early Stages of Planning. These announcements consist mainly of major new refineries now in planning and are assumed to be targeted for the 1980 to 1985 time period.

A third assumption used in making growth projections was that only 30 percent of the announced new East Coast refineries would be built. The basis for this assumption is the significant opposition from local environmental groups and state legislatures. This opposition is singularly strong on the East Coast.

The historical opposition to East Coast refinery construction is illustrated in Table 4.3-1. An examination of this table shows that the Fuels Desulfurization Corporation and its subsidiaries proposed four sites for a 200,000 bbl/day refinery,

TABLE 4.3-1. REFINERIES PLANNED BUT NOT CONSTRUCTED BECAUSE OF OPPOSITION ON ENVIRONMENTAL GROUNDS

Company	Location	Barrels/Day	Final Action Blocking Project
Shell Oil Co.	Delaware Bay, DE	150,000	State reacted by legislature is passing bill forbidding refineries in Coastal Area.
Fuels Desulfurization[1]	Riverhead, RI	200,000	City Council opposed project and would not change zoning.
Maine Clean Fuels[1]	South Portland, ME	200,000	City Council rejected proposal.
Maine Clean Fuels[1]	Searsport, ME	200,000	Maine Environmental Protection Board rejected proposal.
Georgia Refining Co.[1]	Brunswick, GA	200,000	Blocked through actions of Office of State Environmental Director.
Northeast Petroleum	Riverton, RI	65,000	City Council rejected proposal.
Supermarine, Inc.	Hoboken, NJ	100,000	Hoboken Project withdrawn under pressure from environmental groups.
Commerce Oil	Jamestown Island, RI	50,000	Opposed by local organizations and contested in court.
Stewart Petroleum	Piney Point, MD	100,000	Rejected by St. Mary's County voters by referendum on July 23, 1974.
Olympic Oil Refineries, Inc.[2]	Durham, NH	400,000	Withdrawn after rejection by local referendum.
C. H. Sprague & Son	Newington, NH	50,000	Voted down in community vote on June 28, 1974.
Belcher Oil Co.	Manatee County, FL	200,000	Voted against in referendum September 10, 1974.

[1] Maine Clean Fuels and Georgia Refining Company are subsidiaries of Fuels Desulfurization and the refinery in question is the same in each case, so the capacity in barrels per day is not additive, but the incidents are independent and additive.

[2] Olympic is still considering other nearby sites.

each of which was ultimately rejected because of regional opposition. Thus, it may be logical for oil companies to announce plans for several refineries in the hope that one might be permitted. In such cases the other projects would be cancelled. This could also occur if several companies announced refineries in the same area, bidding for the same product market.

Table 4.3-1 also shows eight other East Coast refinery projects which have been blocked in recent years. No new refineries outside of the East Coast area were listed as being blocked due to environmental opposition.

A final consideration in the evaluation of this assumption is the impact on resulting projected refining capacity. If announced East Coast refining capacity is used for the projections a considerable surplus in refining capacity results for the "most likely" case. It is therefore felt that if East Coast refining capacity is restricted to 30 percent of that announced, the projections will be more realistic.

The dates for completion of the "Uncertain, Undefined, or Early Stages of Planning" projects are generally absent or vague. It was assumed that they would be completed during the period of 1980-1985. New refineries require several years of planning to complete the administrative, engineering, and construction phases. Since incremental or major expansions generally require considerably less lead time, it would seem reasonable to assume that expansion plans (as opposed to grass-roots projects) would not be announced as far ahead of time, and would not appear in announced 1980-1985 plans at this time. It seems evident, however, that a significant portion of additional refining capacity will be added in this manner.

An analysis of 1975-1980 growth indicates that incremental expansions over this five year period will average 1.4 percent per year. Data from Trends in Refinery Capacity and Utilization indicate 1975 expansion capacity at 1.2 percent.[13] To estimate 1980-1985 expansion growth, a value of 1.0 percent per year was used. This allows a conservative estimate of expansion capacity in addition to the expansions itemized in Appendix B.

Refinery Growth Projections: Restricted East Coast Construction

Under the maximum refining growth scenario refinery growth for the 1980-1985 time period was projected according to announced "Uncertain, Undefined, or Early Stages of Planning" projects. It was assumed that only 30 percent of the new refineries announced for the East Coast would be completed. In addition to the announced new refineries, incremental and major expansions were presumed at existing facilities in potential growth areas at a rate of 1 percent per year.

Using these assumptions, new refining capacity of 2.1 MM bbl/day and expansion capacity of 1.1 MM bbl/day would be added. The total 1985 refining capacity would amount to 21.5 MM bbl/day. This capacity is slightly higher than the demand projected under the $13/bbl BAU scenario. Product imports of 0.7 MM bbl/day would be required under the $13/bbl PESS scenario.

The additional new refining capacity would be projected to AQCR's for which the projects are announced, with the new East Coast capacity reduced to 30 percent of that announced. Under this procedure, new East Coast refinery capacity amounts to 0.685 MM bbl/day, and new refining capacity of 1.43 MM bbl/day is projected to AQCR's in the rest of the country.

Appendix C lists the 1985 refining capacity by AQCR under the restricted East Coast maximum refining growth scenario. Table 4.3-2 presents a summary of refinery capacity by region of the country. It was necessary to manipulate the data by region as opposed to AQCR as domestic oil and foreign oil supply data could not be organized by AQCR.

TABLE 4.3-2. PROJECTED REFINERY CAPACITY FOR MAXIMUM GROWTH SCENARIO I IN 10^6 BARRELS PER YEAR

Region of Country	1975 Capacity	1985 Projected Capacity
Gulf Coast	2332.4	3566
East Coast	609.6	1284.8
West Coast	897.9	1427.2
Inland, Great Lakes	1547.6	1715

Refinery Growth Allocation: Unrestricted East Coast Construction

With this method, the completion of all "Uncertain, Undefined, or Early Stages of Planning" projects is assumed, and refinery growth for the maximum refinery growth scenario is allocated on the basis of announced plans.

In addition to the announced new refineries, incremental and major expansions were presumed at existing facilities in potential growth areas at a rate of 1 percent per year.

With these assumptions, 2.7 MM bbl/day refining capacity will be added in East Coast locations, and 1.4 MM bbl/day refining capacity will be projected as an addition to the rest of the country. In addition 1.1 MM bbl/day of expansion capacity is projected for potential growth areas. The total of 5.2 MM bbl/day of additional U.S. refining capacity provides a capacity surplus of 2.5 MM bbl/day over the demand projected in the $13 bbl BAU scenario. There is a surplus capacity of 1.0 MM bbl/day in the $13/bbl PESS scenario.

The refining capacities in AQCR's affected by this assumption are listed in Table 4.3-3. As the unrestricted East Coast option produces capacities well in excess of the projection, it was decided to use the restricted growth case previously presented.

TABLE 4.3-3. PROJECTED REFINING CAPACITY
UNRESTRICTED EAST COAST OPTION (BBL/DAU)

AQCR	1985 Capacity
41	400,000
42	400,000
45	1,252,646
110	250,000
115	428,500
119	100,000
121	800,000
158	208,637
223	301,450

4.3.2.2 Scenario II - Minimum Growth

The minimum transportation of crude oil and, therefore, minimum refining capacity scenario assumes $13/bbl for domestic oil and business as usual conditions. This scenario is also referred to as a "most likely" to occur possibility. Under the assumptions of this scenario petroleum product demands will increase only 2.0 percent per year as opposed to historical growth rates of 3.5 percent per year, resulting in a total demand of 19.8 MMB/D in 1985 compared to 15.8 MMB/D in 1975. The lower growth rate is the expected result of higher priced petroleum products.

Domestic production is expected to increase from 1975 levels of 8.5 MMB/D to 13.9 MMB/D, spurred primarily by higher crude oil prices. Imports are expected to remain at about the 1975 level, increasing only 0.1 MMB/D to 5.9 MMB/D. Marine transportation of foreign oil should remain at about the same level as in 1975 with higher domestic crude oil marine transportation, primarily involving Alaskan crude.

The generally lower demand for petroleum products associated with this scenario results in fewer refinery growth projects. As a result, it is assumed that no new refineries will be built between 1975 and 1985 with the exception of those currently under construction or firmly committed for this time period. The required increase in refinery capacity will be supplied by expansion of existing refineries at a rate of 2 percent per year. The expansion growth was projected for growth potential areas.

Growth Potential AQCR's

Certain regions are preferred for refining growth due to considerations of crude availability, land, water, power, labor, and market location. Historically, the refining industry has tended to concentrate in certain regions. Therefore, to establish the AQCR's preferred for growth in the expansion studies, growth potential was based on announced intentions of industry to build new refineries or to significantly expand present facilities. It is felt that this firmly establishes an area growth potential. A second consideration for expansion studies is, of course, that there be current refining capacity located in that area where growth potential is assessed.

Growth potential is established on the basis of industry announcements. To reduce the number of AQCR's considered and simplify calculations, cut-off limits of 30,000 bbl/day for 1975-1980 growth and 100,000 bbl/day for 1980-1985 growth were established. This assumption affects a significant number of AQCR's but only 2 percent of 1975-1980 capacity and 5 percent of 1980-1985 capacity.

The second condition is that current refining capacity is necessary before expansions can take place. The capacities dealt with are AQCR capacities. A cut-off level of 100,000 bbl/day present capacity was used to simplify calculations. This assumption impacts 6 of 29 growth potential AQCR's but affects only 1.4 percent of the present capacity in these AQCR's. Since expansions are directly proportional to the present capacity, the results are not significantly affected.

In addition, there were twelve AQCR's for which industry has announced growth plans, but in which there is no present capacity. This indicates growth potential for that AQCR and also growth potential for the area. Because it is impossible to expand in the specific AQCR, expansion in a neighboring AQCR was allowed if that AQCR had present refining capacity. AQCR's 109, 110, 116, 119, and 121 had no neighboring AQCR with present refining capacity. Several other AQCR's with no present capacity were located adjacent to growth potential AQCR's and it was assumed that this growth would account for the area growth potential. For example, AQCR 193 was a growth potential AQCR with no present capacity. Neighboring AQCR's 228 and 229 were expanded to account for the area growth potential. Similarly, expansion in AQCR 162 was substituted to account for the growth potential of AQCR 158.

Table 4.3-4 lists the growth area AQCR's, the 1975 capacities, and the 1980 and 1985 capacities at an expansion rate of 2 percent per year.

TABLE 4.3-4. REFINERY CAPACITY IN GROWTH AREA AQCR's (BBL/DAY)

Growth Area AQCR	1975 Refining Capacity	20% Overall Expansion	
		1980	1985
5	343,300	337,630	411,960
22	116,468	128,115	139,762
24	1,078,635	1,186,499	1,294,362
30	626,000	688,600	751,200
43	353,000	388,300	423,600
45	993,000	1,092,300	1,191,600
60	101,750	111,925	122,100
70	430,750	473,825	516,900
106	2,997,025	3,296,728	3,596,430
158 (162)	111,385	122,524	133,662
193 (228,229)	380,900	418,990	457,080
214	476,725	524,398	572,070
216	1,631,725	1,794,898	1,958,070
223	53,000	58,300	63,600
	9,693,663	10,663,032	11,632,396

Minimum Growth Allocation to AQCR's

The 1980 and 1985 refining capacities are listed by AQCR for the minimum growth scenario in Appendix C. The refinery expansions are summarized by region in Table 4.3-5.

TABLE 4.3-5. PROJECTED REFINERY CAPACITY FOR MINIMUM GROWTH SCENARIO II IN 10^6 BARRELS PER YEAR

Region of Country	1975 Capacity	1985 Projected Capacity
Gulf Coast	2332.2	2993
East Coast	609.6	719
West Coast	897.9	1073.1
Inland, Great Lakes	1547.6	1547.6

4.3.3 Projection of Crude Oil Movements

4.3.3.1 Scenario I

Scenario I would require some 12.6 MMB/D of petroleum imports to supply U.S. demands in 1985. This is a 117 percent increase over 1975 imports. Of this import total, some 8.8 MMB/D is assumed to be crude oil imports to U.S. refineries (assuming the same crude oil to total petroleum products ratio as in 1975).

If transportation patterns remain the same as in 1975, most of this increase will be absorbed by higher imports from Africa and the Middle East. Canadian imports are expected to stop prior to 1985. Most of the foreign crude will, therefore, be shipped to the Gulf Coast and East Coast. Table 4.3-6 summarizes the expected mix of foreign crude to domestic crude at these refineries.

TABLE 4.3-6. PROJECTED CRUDE OIL SUPPLIES TO REFINERIES 1985 SCENARIO I - MAXIMUM GROWTH (10^5 BARRELS PER YEAR)

Refining Region of Country	Projected Refinery Receipts	Domestic Crude Oil Supply	Foreign Crude Oil Supply
Gulf Coast	2661.5	1103.3	1558.2
East Coast	1074.8	18.3	1056.5
West Coast	1008.5	523.0	485.5
Inland, Great Lakes	1393.4	1393.4	--

Domestic Oil Production

Domestic oil production is projected to decline slightly from the 10.0 MMB/D level of 1975 to 9.6 MMB/D. This total will include 3.4 MMB/D from the lower 48 states, Outer Continental Shelf (OCS) and Alaska. It is not known how much of the OCS oil will be transported by marine shipping. In the past the primary method of transporting offshore crude to refineries has been by ship and barge.[14,15] It is assumed that all of the 1.2 MMB/D of oil produced in Alaska will be shipped by marine transportation; however, the destination of this oil is in doubt. The likely routes are to Southern California and the Gulf Coast. Both of these areas could experience a significant increase in marine transportation of domestic crude. The loading operations will be offshore and in Alaska.

If all the Alaskan oil is shipped to the West Coast, the total amount in 1985 would be 620.5 x 10^6 barrels, well in excess of the projected domestic feedstocks to this area summarized in Table 4.3-6. Sufficient refining capacity is projected in the area to handle the crude if this situation occurs. The impact would probably be to reduce foreign oil shipments to this area in favor of the Gulf Coast and East Coast refineries.

Foreign Oil Imports

This scenario assumes a very high importation of crude oil from foreign countries. The 11 percent increase over 1975 levels would result in large scale increases in crude oil shipping to the U.S.

Projection of foreign oil imports were made assuming transportation patterns will be the same as in 1975. The increase was expected to be made up by African and Middle Eastern countries as a preponderance of world reserves are in that area. The Venezuelan government has announced that production levels of imports will not be increased beyond the 1975 totals. As a result, all of the additional imports were assumed to come from Africa and the Middle East.

The projections are summarized in Table 4.3-7. From the table it can be seen that the major impact will be from the Gulf Coast and East Coast refinery centers.

4.3.3.2 Scenario II

Scenario II would require an increase in domestic oil production of about 38 percent by 1985 as compared to the 1975 totals. Foreign oil imports would remain about the same as in 1975. Canadian oil, however, is expected to be stopped by 1985. In order to make up the difference, increased oil imports from Africa and the Middle East are projected.

It was assumed that the transportation patterns for foreign oil in 1975 would remain the same thru 1985. The foreign crude was allocated to regions according to this assumption. A summary of domestic and foreign crude oil to U.S. refinery centers is presented in Table 4.3-8. As a direct result of the high domestic production and low foreign import, most of the feedstocks to the Gulf Coast and West Coast are projected to be domestic oil (as compared to the higher imports and lower domestic production of Scenario I).

TABLE 4.3-7. SUMMARY OF CRUDE OIL IMPORT PROJECTIONS FOR 1985 BY REGION OF ORIGIN AND REFINERY REGION - SCENARIO I (ALL FIGURES IN 10^6 BARRELS PER YEAR)

Refinery Region	Africa	Middle East	Canada	South America	Indonesia	Trinidad	Mexico
Gulf Coast	908.6	544.0	--	29	17.8	35.1	23.6
East Coast	567.7	376.1	--	92.7	11.3	6.9	1.7
West Coast	49.4	286.5	--	35	114.4	--	--
Inland Great Lakes	--	--	--	--	--	--	--
Puerto Rico	18.5	55.5	--	43.7	--	0.7	2.4

TABLE 4.3-8. PROJECTED CRUDE OIL SUPPLIES TO REFINERIES 1985 SCENARIO II - MINIMUM GROWTH (10^6 BARRELS/YEAR)

Refining Region of Country	Projected Refinery Receipts	Domestic Crude Oil Supply	Foreign Crude Oil Supply
Gulf Coast	2704.4	2019.9	684.5
East Coast	652	163.1	488.9
West Coast	939.5	637.5	302
Inland, Great Lakes	1445	1445	--

Domestic Oil Production

Alaskan production is expected to reach 3.1 MMB/D by 1985 in this scenario. Almost all of this oil can be expected to be moved by ships to the lower 48 states. If substantial quantities are sold to Japan, the effect would probably be to ship Arabian light to the Gulf Coast on approximately a one to one ratio with the Alaskan crude. Lower 48 states OCS production is projected to reach 2.1 MMB/D in Scenario II, most of which is assumed to be transported by ship and barge. The major OCS production should be in the Gulf of Mexico. Therefore, the shipping patterns will be to Gulf Coast refineries or to marine terminals near the Mississippi River for barge transport to Midwest refineries where Canadian cutbacks will create shortages.

Foreign Oil Imports

The importation levels for foreign oil will remain about the same in 1985 as in 1975, but there will be a necessity for increased imports from Africa and the Middle East to offset losses from Canada. The impact will be to increase the foreign oil to domestic oil ratio slightly in the Gulf Coast and East Coast refineries. There will be an accompanying increase in marine shipments to those areas.

The projections of foreign oil imports are summarized in Table 4.3-9.

4.3.4 Projections of Gasoline Transportation

The refining projections were translated into gasoline outputs for the two scenarios by assuming that the ratio of gasoline to crude oil refinery receipts will remain the same through 1985. Data from U.S. Bureau of Mines Mineral Surveys for 1975 were used to calculate the ratio of gasoline output to refinery capacity for the four regions.[16] The projections of gasoline output are summarized in Table 4.3-10.

The outputs for scenario II are significantly lower due to the higher price structure driving down demand for refined products.

Demand projections for gasoline products were taken from the FEA energy forecast.[12] The data are for the 1985 reference case and represent projected demands for gasoline by region, based on population projections. These demand regions were compared to the refinery regions in order to calculate the deficit or surplus of gasoline in that region. The results are summarized in Table 4.3-11.

These figures indicate a large surplus of gasoline production in the Gulf Coast region with large deficits on the East Coast and Inland. The West Coast is projected to produce about the same amount as demand. It is apparent from the table that large quantities of gasoline will be transported from the Gulf Coast to the East Coast and Inland.

TABLE 4.3-9. SUMMARY OF CRUDE OIL IMPORT PROJECTIONS FOR 1985 BY REGION OF ORIGIN AND REFINERY REGION - SCENARIO II (ALL FIGURES IN 10^6 BARRELS PER YEAR)

Refinery Region	Country or Geographical Region of Imports						
	Africa	Middle East	Canada	South America	Indonesia	Trinidad	Mexico
Gulf Coast	360.8	218	--	29	17.8	35.1	23.6
East Coast	225.4	150.7	--	92.7	11.3	6.9	1.7
West Coast	19.6	114.8	--	35	114.4	--	--
Inland, Great Lakes	--	--	--	--	--	--	--
Puerto Rico	7.4	22.3	--	43.7	--	0.7	2.4

TABLE 4.3-10. PROJECTED GASOLINE OUTPUT BY REFINERY REGION, 1985

Region		Output (10^6 barrels/year)	
		Scenario I	Scenario II
Gulf Coast		1256.2	1276
East Coast		476.1	288.8
West Coast		531.5	495.1
Inland		624.2	647.4
	Totals	2888.0	2707.3

TABLE 4.3-11. RELATIONSHIP OF DEMAND FOR GASOLINE TO REFINERY OUTPUT BY REGION, 1985

(10^6 barrels/year)

Region	Scenario I			Scenario II		
	Production	Demand	Surplus (Deficit)	Production	Demand	Surplus (Deficit)
Gulf Coast	1256.6	298.1	958.5	1276.0	279.4	996.6
East Coast	476.1	940.0	(463.9)	288.8	881.2	(592.4)
West Coast	531.5	577.1	(45.6)	495.1	541	(45.9)
Inland	624.2	1072.7	(448.5)	647.4	1005.6	(358.2)
Total	2888.4	2887.9	0.5	2707.3	2707.2	0.1

The gasoline produced at the refinery centers is stored temporarily and then moved to bulk terminals by pipeline, ship, barge, truck and tank car. Most of the gasoline transported is moved by pipeline. About 50 percent of the bulk terminals in the country listed pipelines as the primary method of receiving petroleum liquids in 1975. It is not known what percent of the total U.S. storage capacity was represented by those terminals. In addition, it is not known what quantity of gasoline products was transported by this method. For these reasons it is difficult to accurately estimate how much gasoline was transported by what method. Only major trends can be addressed.

About 15 percent of the bulk terminals received petroleum products by ships as the primary method while barges accounted for 30 percent. When the data is analyzed by region some trends do develop. Approximately 60 percent of the bulk terminals on the East Coast received gasoline primarily by ship and barge with barges accounting for 40 percent and ships for the remaining 20 percent. On the Gulf Coast slightly less than 30 percent of the terminals received gasoline by barges, while ships accounted for about 1 percent. On the West Coast most of the traffic is by marine transportation, with 32 percent being supplied by barges and 24 percent by ship. Surprisingly, almost 30 percent of inland terminals are supplied by ships and barges. Ships account for about 9 percent, probably due to shipping on the Great Lakes, and barges transport 20 percent.

Data were collected from the American Waterways Operators, Inc. for traffic on inland waterways (including the intercoastal canal).[17] The data are tabulations of total quantities of gasoline transported over various shipping and barging routes. Most of the traffic is on the Mississippi River, the main East Coast waterways (including the Delaware River, Chesapeake Bay and Hudson River) and the Houston Ship Channel. The data suggest heavy shipping traffic from the Gulf Coast refineries up the Mississippi to bulk terminals inland and to East Coast facilities. It is assumed that these traffic patterns will continue through 1985 with large quantities of gasoline being shipped up the Mississippi and to the East Coast to offset the deficits in the supply and demand situation. It should be remembered that the economics of pipeline, ship and barge transportation will heavily influence the primary method of transportation.

5.0 OPERATIONAL CONTROL TECHNOLOGY

This section addresses the potential reductions in marine terminal emissions which can be obtained by altering marine terminal operating procedures. Hydrocarbon compounds are emitted from ships and barges during loading and unloading operations at marine terminals. One proposed method for reducing these emissions is through the use of vapor recovery units. However, there are several disadvantages associated with vapor recovery units. These disadvantages include cost, added safety risk, ship retrofit problems, and reduced dock space.

A possible alternative to the use of vapor recovery units is the use of modified marine terminal operations. Many marine terminal operations already practiced, or easily put into practice, have the potential to lower marine terminal emissions by moderate amounts. If applied collectively, these alternative marine terminal operating procedures can significantly reduce loading and unloading emissions. Section 5.1 contains an investigation of the impact of alternate loading procedures and Section 5.2 contains an investigation of the impact of alternate unloading procedures.

5.1 Alternate Loading Procedures

5.1.1 Source and Mechanism of Loading Emissions

A major source of hydrocarbon emissions at marine terminals occurs during loading operations. Hydrocarbon emissions from loading operations are attributable to the displacement to the atmosphere of hydrocarbon vapors residing in empty vessel tanks by products being loaded into the vessel tanks.

Loading emissions can be separated into the arrival component and the generated component. The arrival component of loading emissions consists of hydrocarbon vapors left in the empty cargo tanks from previous cargoes. The generated component of loading emissions consists of hydrocarbon vapors generated in the cargo tanks as hydrocarbon liquids are being loaded.

The arrival component of loading emissions is directly dependent on the true vapor pressure (TVP) of the previous cargo, the unloading rate of the previous cargo, and the cruise history of the cargo tank on the return voyage. The cruise history of a cargo tank may include heel washing, ballasting, butterworthing, vapor freeing, or no action at all. Temperature gradients, vessel motion, and long elapse times contribute to the well mixing of empty cargo tanks, resulting in almost uniform vapor concentrations in the arrival component. The arrival component for vessels loading gasoline characteristically range from 0 vol % to 20 vol % hydrocarbons, but can exceed 50 vol %.

The generated component of loading emissions is produced by the evaporation of hydrocarbon liquid being loaded into the vessel tank. The quantity of hydrocarbons evaporated is dependent on both the true vapor pressure of the hydrocarbons and the loading practices. The loading practice which has the greatest impact on the generated component is the loading rate.

An example profile of hydrocarbon vapor concentrations in a vessel tank during loading is presented in Figure 5.1-1.[7] As indicated in the figure, the hydrocarbons present throughout most of the vessel tank vapor space are contributed by the arrival vapor component and the concentration is almost uniform. There is a sharp rise in hydrocarbon vapor concentration just

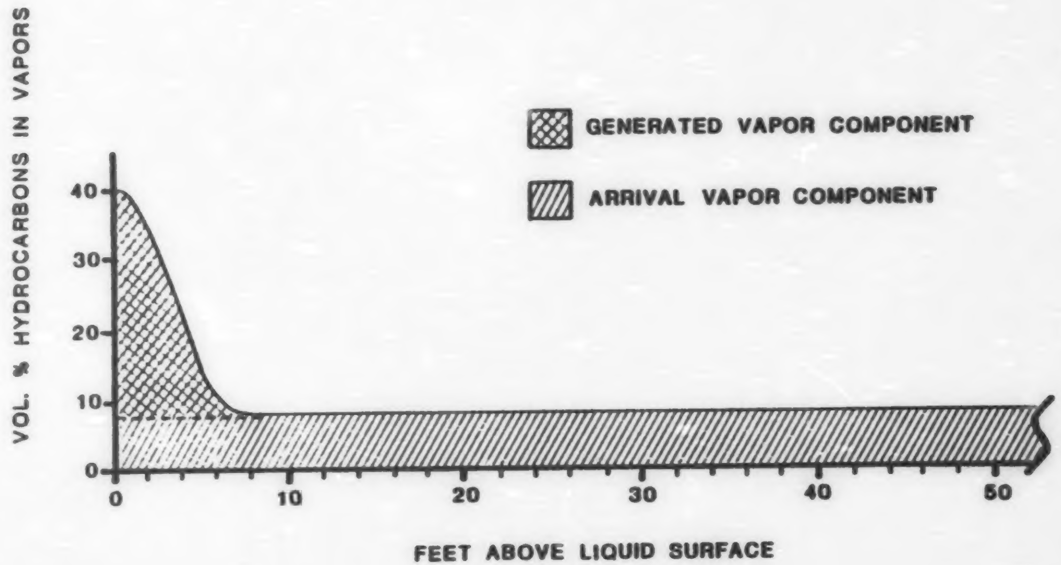


FIGURE 5.1-1 EXAMPLE PROFILE OF GASOLINE LOADING EMISSIONS - UNCLEANED TANKS

above the liquid surface. This is the generated component. The generated component, also called a vapor blanket, is attributable to evaporation of the hydrocarbon liquid being loaded.

From Figure 5.1-1 it is apparent that for large vessels with 55 foot ullages, the average hydrocarbon concentration of vapors vented during loading operations is primarily dependent on the arrival component. For smaller vessels such as barges with 12 foot ullages the average hydrocarbon concentration in the vented loading vapors is dependent on both the generated component and the arrival component.

5.1.2 Emissions from Dirty Tanks

The greatest emission losses from loading gasoline at marine terminals occur during the loading of gasoline into the uncleaned tanks of a vessel in dedicated service. This situation would represent an uncontrolled, worst case situation.

Vessels in dedicated service consistently carry the same cargo. The uncleaned tanks of empty dedicated gasoline vessels contain significant amounts of hydrocarbon vapor remaining from the previous voyage. Some typical hydrocarbon emission rates for loading uncleaned vessels in dedicated gasoline service are presented in Table 5.1-1. As these emission rates indicate, the arrival component constitutes a major portion of the total loading emissions. It should also be pointed out that these are average emission factors, and that actual emission rates can vary greatly.

Figure 5.1-1 also represents an example concentration profile of the hydrocarbon emissions vented from loading gasoline into uncleaned cargo tanks.

TABLE 5.1-1. HYDROCARBON EMISSIONS FROM LOADING GASOLINE INTO UNCLEANED VESSELS

Vessel Type	Hydrocarbon Emissions ($lb/10^3$ gal)			
	Range	Average	Arrival Component	Generated Component
Tanker	0.4 to 4	2.4	1.5	0.9
Ocean Barge	0.5 to 5	3.3	2.0	1.3
Barge	1.4 to 9	4.0	2.8	1.2

Source: Reference 7

5.1.3 Effects of Tank Cleaning

One means of lowering marine terminal loading emissions is through the application of tank cleaning techniques. Tank cleaning lowers loading emissions by lowering the arrival component. The three most common tank cleaning procedures are heel washing, butterworthing, and gasfreeing.

Heel Washing

The heel of a cargo tank is the residual puddles of hydrocarbon liquids remaining in cargo tanks after emptying. These residual liquids will eventually evaporate and contribute to the arrival component of subsequent vessel loading emissions. By washing out this heel with water, Amoco Oil Company found that they were able to reduce the average hydrocarbon concentration in the emissions from subsequent filling operations from a level of 5.7 vol % to a level of 2.7 vol % hydrocarbons.[18]

Butterworthing

Butterworthing is the washing down of tank walls in addition to the washing out of tank heels. Normally, butterworthing is accomplished by lowering a revolving nozzle into the tank and spraying sea water on the walls. Occasionally detergents are added to the water to improve cleaning ability. The hydrocarbon liquids washed from the tanks are stored in a slops tank for disposal onshore.

Gasfreeing

Heel washing and butterworthing lower arrival vapor components by removing residual hydrocarbon liquids from tank walls and bottoms before they evaporate. However, these two techniques do not affect hydrocarbon vapors which have already formed. Marine vessels can purge the hydrocarbon vapors from empty and ballasted tanks during the voyage by several gasfreeing techniques which include air blowing and removal of ullage dome covers. A combination of tank washing and gasfreeing will effectively remove the arrival component of loading emissions.[19]

Table 5.1-2 presents typical hydrocarbon emission factors for loading gasoline into cleaned vessel tanks. An example concentration profile of these loading emissions is presented in Figure 5.1-2. Effectively, all of the hydrocarbon emissions from loading clean vessels are attributable to the generated vapor component. Cleaning the vessel tanks eliminates the arrival vapor component.[19] (See Figure 5.1-1)

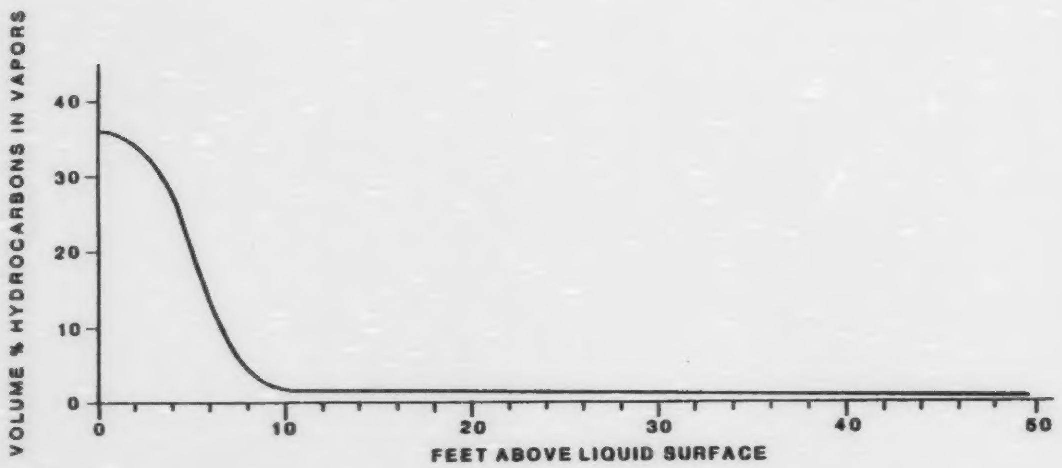


FIGURE 5.1-2 EXAMPLE PROFILE OF GASOLINE LOADING EMISSIONS - CLEANED TANKS

TABLE 5.1-2. HYDROCARBON EMISSIONS FROM LOADING GASOLINE INTO CLEANED VESSELS

Vessel Type	Hydrocarbon Emissions (lbs/10^3 gal) Range	 Average
Tanker	0 - 2.3	1.0
Ocean Barge	0 - 3	1.3
Barge	not available	1.2

Source: Reference 7

5.1.4 Effects of Ballasting

Ballasting is the act of partially filling empty cargo tanks with water to maintain a ship's stability and trim. Figures 5.1-3, 5.1-4, and 5.1-5 present sample hydrocarbon vapor profiles for empty gasoline cargo tanks prior to ballasting, for ballasted gasoline cargo tanks, and for gasoline cargo tanks after ballast discharge.[18] As Figure 5.1-3 indicates, prior to ballasting, empty cargo tanks normally contain an almost homogeneous concentration of residual hydrocarbon vapors. When ballast water is taken into the empty tank, Figure 5.1-4 indicates that hydrocarbon vapors are vented but that the remaining vapors not displaced retain their original hydrocarbon concentration. Upon arrival at a loading dock, a ship discharges its ballast water and draws fresh air into the tank. The fresh air dilutes the arrival vapor concentration and lowers the effective arrival vapor concentration by an amount proportional to the volume of ballast used (Figure 5.1-5). Although ballasting practices vary quite a bit, individual tanks are ballasted about 80 percent and the total vessel is ballasted approximately 30 percent to 40 percent.[18] Consequently, ballasting potentially lowers the individual tank arrival component by 80 percent and lowers the total ship arrival component by 30 percent to 40 percent. Table 5.1-3 presents typical levels of hydrocarbon emissions

FIGURE 5.1-3 HYDROCARBON PROFILE PRIOR TO BALLASTING AN EMPTY TANK

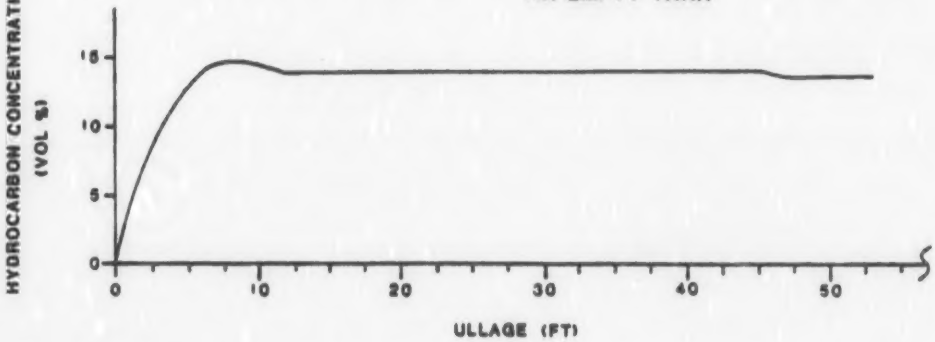


FIGURE 5.1-4 HYDROCARBON PROFILE OF A BALLASTED TANK

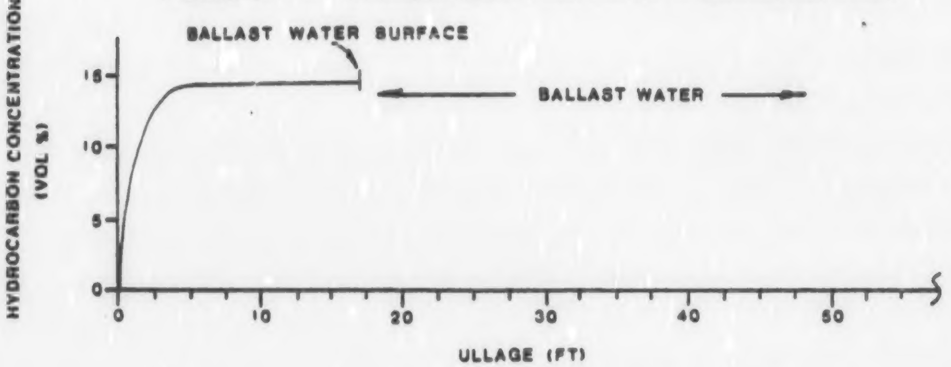
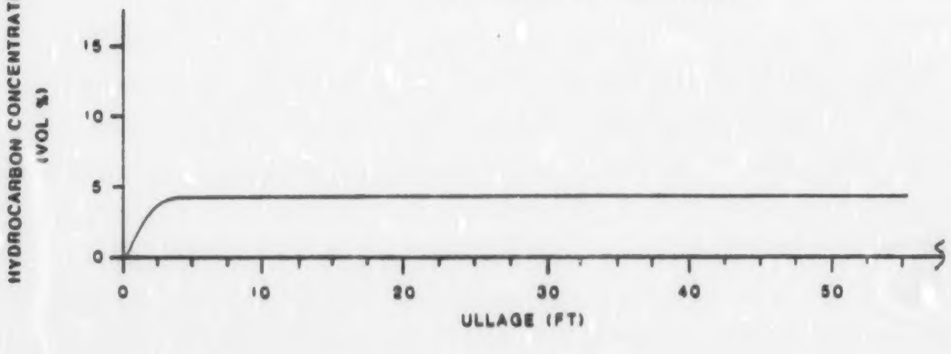


FIGURE 5.1-5 HYDROCARBON PROFILE OF AN EMPTY TANK AFTER BALLAST DISCHARGE



from loading gasoline into vessel tanks which have been filled with ballast water.[7]

TABLE 5.1-3. HYDROCARBON EMISSIONS FROM LOADING GASOLINE INTO CARGO TANKS USED FOR BALLAST

Vessel Type	Hydrocarbon Emissions ($lbs/10^3$ gal) Ranges	Average
Tanker	0.4 - 3	1.6
Ocean Barge	0.5 - 3	2.1
Barge	not used	not used

Source: Reference 7

Regulations recently proposed by the U.S. Coast Guard will require all new and existing foreign and U.S. tankers over 20,000 dwt used in the U.S. oil trade to be equipped with segregated ballast. Tankers equipped with segregated ballast have tanks which are specifically designated for ballast and cannot be used for cargo transport. Assuming a vessel could maintain stability strictly through the use of segregated ballast, then ballasting emissions would essentially be eliminated. If adopted, the Coast Guard regulations would become fully effective within the next five years.[20]

5.1.5 Effects of Loading Rate

Marine terminal loading rates noticeably affect marine loading emissions and therefore represent another potential method for controlling marine loading emissions.

Currently, marine terminal loading rates are far from standardized. Reported marine terminal loading rates in the Houston-Galveston area ranged from 1000 bbl/hr to 15,000 bbl/hr for each loading line. Loading rates are highly dependent on the size of the individual dock equipment and on the size of each ship's piping system. Normal loading rates for barges are 2000 bbl/hr to 5000 bbl/hr and normal loading rates for ocean barges and tankers are 5000 bbl/hr to 10,000 bbl/hr.

Studies conducted in 1975 by Atlantic Richfield and Amoco Oil Co. show that the initial loading rate, bulk loading rate, and final loading rate all noticeably affect marine loading emissions. The optimum selection of these loading rates presents a potential method for lowering loading emissions without the use of vapor recovery equipment.[21,18]

Initial Fill Rate

There is a significant degree of splashing and liquid turbulence as cargoes are first pumped into empty vessel tanks. This splashing and turbulence results in rapid hydrocarbon evaporation and the formation of a vapor blanket. By reducing the initial velocity of cargoes entering empty tanks, it is possible to reduce the turbulence associated with initial tank filling and, consequently, to reduce the size and concentration of the vapor blanket. Table 5.1-4 and Figure 5.1-6 present the results of Amoco Oil Company tests on the effect of slow loading the initial 1 ft. and 2 ft. of gasoline cargo tanks. The slow loading rate used in the Amoco study was one foot of elevation per fifteen to twenty minutes. This is an equivalent loading rate of 700-1000 bbl/hr for both ships and barges.[18]

The information in Table 5.1-4 and in Figure 5.1-6 indicate a 50 percent reduction in vapor blanket size by using slow initial loading rates. For a clean tanker this is equal to a 50 percent emission reduction and for a dirty tanker is equivalent to a 17 percent emission reduction.

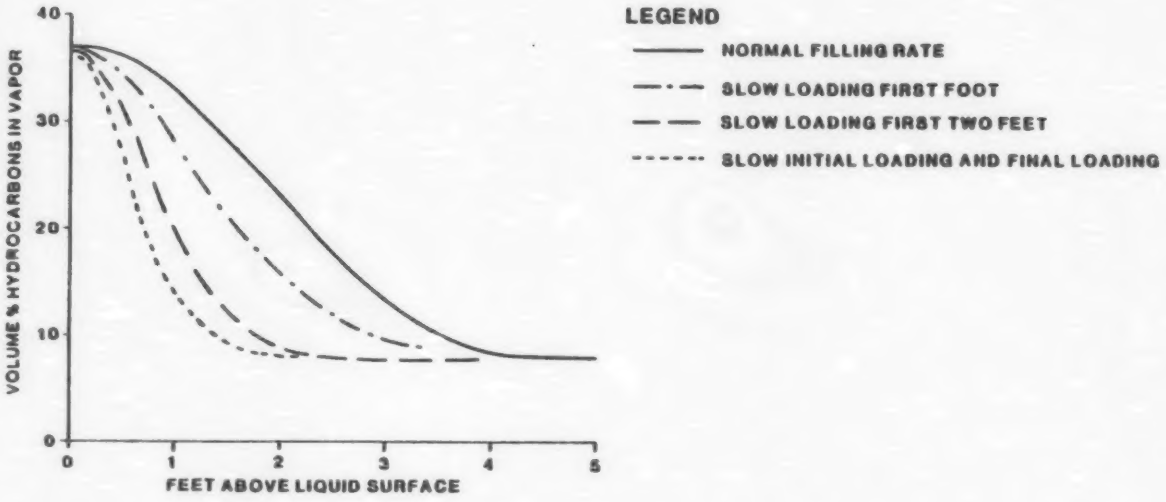


FIGURE 5.1-6 EXAMPLE PROFILES OF GASOLINE LOADING EMISSIONS USING SLOW LOADING RATES
Reference 18

TABLE 5.1-4. HYDROCARBON EMISSIONS FROM SLOW LOADING GASOLINE INTO VESSEL TANKS

Loading Procedure	Reduction in Vapor Blanket	Estimated Emission Rates ($lb/10^3 gal$)					
		Clean Tankers	Dirty Tankers	Clean O.Barges	Dirty O.Barges	Clean Barges	Dirty Barges
Slow Loading Initial 1ft.	25%	0.8	2.3	1.0	3.0	0.9	3.7
Slow Loading Initial 2ft.	50%	0.5	2.0	0.7	2.7	0.6	3.4
Slow Loading Initial 2ft. and final 2ft.	60%-65%	0.4	1.9	0.5	2.5	0.5	3.3

Bulk Fill Rate

Normally, the vapor blanket profile is established by the initial filling rate and undergoes very little change throughout the loading sequence. The bulk loading rate normally has very little effect on the vapor blanket because of the relatively slow diffusion rate of hydrocarbon vapors in air. However, if the bulk loading rate is very slow, or is interrupted by ship personnel, the vapor blanket profile can change appreciably. Marine loading emission tests conducted by Atlantic Richfield indicated that lowering the bulk loading rate of a gasoline tanker from 3300 barrels per hour to 450 barrels per hour raised the average hydrocarbon emission rate from 0.5 $lbs/10^3$ gal to 1.5 $lbs/10^3$ gal. The emissions were tripled.

It is therefore very important to increase the bulk loading rate to the maximum rate after the first two feet of slow loading have been achieved.

Final Fill Rate

As the hydrocarbon liquid level in a marine vessel tank approaches the tank roof, the action of vapors flowing towards the ullage cap vent begins to disrupt the quiescent vapor blanket. Disruption of the vapor blanket results in noticeably higher hydrocarbon concentrations in the vented vapor. Amoco test results from slow final loadings indicate that, although not as significant as slow initial loading, slow final loading can lower the quantity of hydrocarbon emissions from marine vessel loading of volatile hydrocarbon liquids. Table 5.1-4 and Figure 5.1-6 present the results of the Amoco slow loading studies.[18]

The use of slow initial and final loading rates does not necessarily increase overall tanker loading times. High bulk loading rates allow the ship to make up for time lost during slow initial and final tank loadings. Because multiple tanks can be filled simultaneously, one tank can be bulk loading at a rate of 12,000 bbl/hr while another tank is topping off at a rate of 700 bbl/hr, and still another tank is initial loading at a rate of 700 bbl/hr.

5.1.6 Effects of Short Loading

Displacement of the vapor blanket during the final stages of loading gasoline or volatile crudes contributes a significant part of the total hydrocarbon emissions from that tank. By stopping the loading of the cargo tank short, the vapor blanket can be partially or totally kept within the tank. The depth of the blanket usually varies from 3 to 8 feet (see Figure 5.1-1). Therefore, to keep most of the blanket from being displaced, loading must be stopped about 3 to 5 feet from the deck level.[7] For a tank 55 feet deep, short loading would represent a 5.5-9.0 percent loss in potential cargo space.

The effect of short loading on the emissions from gasoline loading onto a ship can be estimated from the numbers in Table 5.1-1. The contribution of the vapor blanket displacement to total tanker emissions is approximately 0.9 to 1.0 $lb/10^3$ gal. Therefore, it can be deduced that short loading can potentially reduce the emissions from clean tankers by 100 percent and the emissions from dirty tankers by 40 percent. Short loading can potentially lower the emissions from ocean barges by a comparable 100 percent and 40 percent. However, due to their small volumes, short loading is not considered economical for standard barges.

There are several consequences of short loading which may adversely affect its ability to reduce emissions from loading operations. This problem becomes apparent when one loading/ unloading cycle for a cargo tank is examined. First, assume a tank is short loaded with a four foot space left from deck level to liquid level. During the time required for transport of the cargo to its destination the space left above the liquid will very likely become saturated with gasoline vapors. As the cargo is unloaded the vapors become diluted with air to a lower concentration. When the ship returns for a new load, the vapor blanket which was not displaced during the previous loading now manifests itself as the arrival component of the emissions and will be displaced as the tank is refilled. Therefore, unless the tanker is cleaned and vapor freed during the return voyage, the net hydrocarbon emissions will not be effectively reduced by short loading.

A second consequence of short loading is that it increases the number of voyages required to ship the same quantity and consequently increases the number of loading operations. The net reduction in emissions must surpass any net increase in voyages to be considered effective.

Another potential problem with short loading standard cargo tanks is that it decreases the stability of tankers and barges. This instability is due to sloshing action in the partially filled tanks and may preclude short loading as an operational procedure for controlling emissions. However, sloshing problems due to short loading may be solved by inclusion of baffles in the upper portion of the tank.

5.1.7 Inerting and P/V Valves

Two other operational control measures which have been suggested are inerting and P/V valves. Inert gas systems provide a source of inert (low oxygen content) gas which is injected in the vapor space of vessel tanks. For cargoes of volatile liquid hydrocarbons, the inert gas prevents the formation of flammable atmospheres in the cargo spaces thereby making tank washing and gas freeing a safe operation. The source of the inert gas may be either boiler flue gases, combustion gases from a specially designed oil fired generator, or generated or bottled pure nitrogen or carbon dioxide.[22]

Studies by British Petroleum on emissions from loading crude oil onto tankers indicate that inerting lowers hydrocarbon emissions slightly. The exact reason for the reduction is not known but it may be attributable to the fact that inerted BP tankers are loaded at a pressure of 1 psig.[23]

The use of P/V valves has also been suggested as an operational control measure. Pressure/vacuum valves would lower loading emissions by effectively compressing the vapor blanket to a thinner size. Theoretically, a 1.5 psig loading pressure should reduce the vapor blanket thickness by 10 percent, but should also increase its hydrocarbon content by 10 percent. The net effect of applying P/V valves on clean tankers would be to lower the loading emissions by less than 10 percent. The net effect on dirty tankers and barges would be to lower the loading emissions by less than 5 percent.

Based on these preliminary results it is estimated that inerting and P/V valves would have a minimal effect as an operational control measure. However, inerting is an effective safety measure which may prove necessary in conjunction with one of the other operational control measures.

5.1.8 Summary of the Impact of Operational Controls on Gasoline Loading Emissions

The information presented in Section 5.1 on loading controls indicates that there is a very good potential for using modifications in operating procedures to control hydrocarbon emissions from marine terminal loading operations. The data presented in Section 5.1 is summarized in Table 5.1-5.

Tankers

Emissions from dirty tankers can be reduced approximately 50 percent by cleaning and vapor freeing the tanks. Emissions from dirty tankers can be reduced approximately 83 percent by combining slow initial and final loading rates with tank cleaning. Finally, the information in Table 5.1-5 indicates that short loading tankers that have been cleaned and slow

TABLE 5.1-5. SUMMARY OF THE IMPACT OF OPERATIONAL CONTROL TECHNIQUES ON GASOLINE LOADING EMISSIONS

	Tankers		Ocean Barges		Barges	
Tank Condition	Emissions ($lb/10^3$ gal)	Control Efficiency Over Dirty Tank	Emissions ($lb/10^3$ gal)	Control Efficiency Over Dirty Tank	Emissions ($lb/10^3$ gal)	Control Efficiency Over Dirty Tank
dirty	2.4	0%	3.3	0%	4.0	0%
ballasted	1.6	33%	2.1	36%	NA[a]	NA
typical[b]	1.2	50%	2.7	18%	4.0	0%
cleaned	1.0	58%	1.3	61%	1.2	70%
cleaned w/slow loading	0.4	83%	0.5	85%	0.5	88%
cleaned w/slow loading and short loading	<0.2	>92%	<0.2	>94%	<0.2	>95%
dirty w/slow loading	1.9	21%	2.5	24%	3.3	18%
dirty w/slow loading and short loading	1.5	37%	2.0	39%	2.8	30%

a. NA - not applicable.

b. The term typical refers to the national average emissions from vessels in 1975.

loaded will potentially lower dirty tanker emissions by more than 92 percent. Slow loading and short loading are relatively ineffective control measures by themselves.

Information reported by Atlantic Richfield and Exxon indicate that tank cleaning is a relatively simple procedure for tankers. Tank cleaning can be conducted out at sea to minimize the release of hydrocarbon vapors in the vicinity of land areas. Whenever a safety hazard is created by tank cleaning, the tank vapors can be purged using inerting gases before attempting the tank cleaning.[21,24]

Data by Amoco indicates that slow initial and final loading is also a relatively simple procedure.[18] However, very little data is available on the problems, if any, involved with short loading tankers. On the surface it appears that the major problem associated with short loading is product sloshing. This problem can be solved by the use of baffles in the tank ceiling.

Initial data indicate that inerting and using P/V valves during filling operations only slightly reduce tanker loading emissions.

Ocean Barges

Ocean barges are very similar to small tankers and therefore respond similarly to operational control techniques. Tank cleaning and vapor freeing reduces hydrocarbon emissions 61 percent. Cleaning and slow loading reduces emissions approximately 85 percent and short loading, cleaning, and slow loading can potentially lower ocean barge emissions by greater than 94 percent.

Operational control techniques for lowering ocean barge emissions are almost as easily applied to ocean barges as they are to tankers. The primary difference is that ocean barges generally carry a smaller crew and have fewer people available to assist in the cleaning operations.

Barges

As Table 5.1-5 indicates, slow loading and short loading in conjunction with cleaning are potentially very effective for reducing hydrocarbon emissions from barge loading operations. However, barges seldom are equipped to be cleaned on a regular basis. Also, because barges are generally confined to inland and intracoastal waterways, vapors purged during barge cleaning would still affect inland ambient hydrocarbon concentrations.

Short loading barges also may not be feasible because it would reduce the effective capacity of barges by 33 percent and increase the required number of barge operations by 50 percent. Consequently, the most applicable operational control technique for barges is probably slow initial and final loading. Slow loading will potentially reduce barge loading emissions by 18 percent.

5.2 Alternate Unloading Procedures

5.2.1 Source and Mechanism of Unloading Emissions

Unloading emissions are hydrocarbon emissions displaced during ballasting operations at the unloading dock subsequent to unloading a volatile hydrocarbon liquid such as gasoline or crude oil. During the unloading of a volatile hydrocarbon liquid, air drawn into the emptying tank mixes with hydrocarbons evaporating from the liquid surface. The greater part of the hydrocarbon vapors normally lies along the liquid surface in a vapor blanket. However, throughout the unloading operation, hydrocarbon liquid clinging to the vessel walls will continue to evaporate and to contribute to the hydrocarbon concentration in the upper levels of the emptying vessel tank. Figure 5.2-1 presents a hypothetical profile of gasoline vapor concentrations in a vessel tank during ballasting. If significant temperature gradients exist between cargo temperature and the ambient temperature, they will create convection currents which in time will disrupt the vapor blanket and promote a homogeneous hydrocarbon vapor concentration throughout the tank.

Before sailing, an empty marine vessel must take on ballast water to maintain trim and stability. Normally, on vessels that are not fitted with segregated ballast tanks, this water is pumped into the empty cargo tanks. As ballast water enters cargo tanks, it displaces the residual hydrocarbon vapors to the atmosphere generating the so termed, "unloading emissions". Although ballasting practices vary quite a bit, individual tanks are ballasted from 80 percent to 100 percent and the total vessel is ballasted approximately 40 percent.[18]

Ballasting emissions have not been studied in the same detail as loading emissions. Some sources have reported severe vapor stratification and very sharp vapor blankets.[23] Other sources have reported high levels of mixing and very little vapor concentration gradient.[7] Emissions estimates range from very low to 2-3 lbs. of hydrocarbons per thousand gallons of ballast.

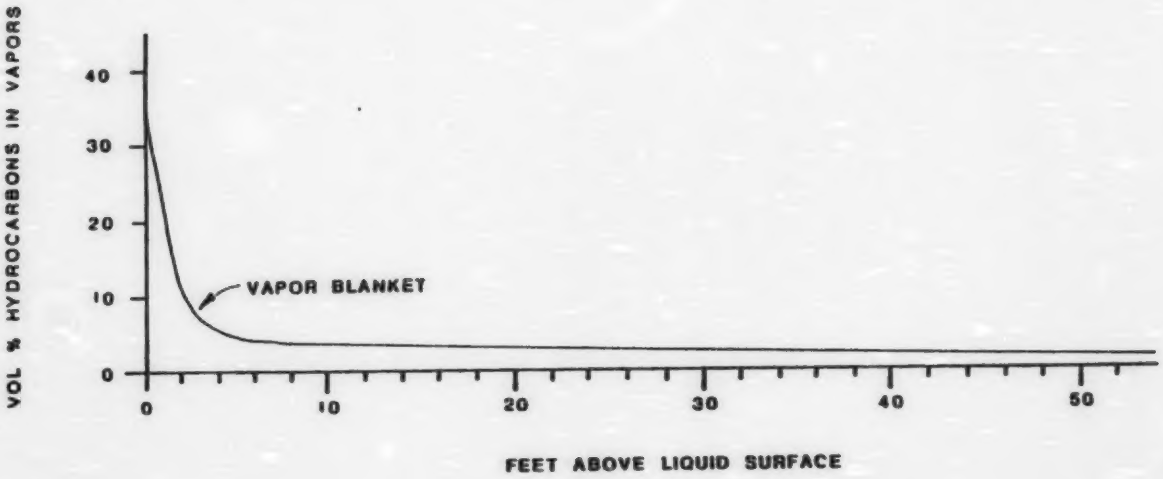


FIGURE 5.2-1 EXAMPLE PROFILE OF GASOLINE BALLASTING EMISSIONS

5.2.2 Operational Control Technology

Two of the most promising operational control techniques for controlling ballasting emissions are segregated ballast and short ballast. Segregated ballast involves the use of special ballast tanks, not cargo tanks, for storing ballast water. Since these tanks are used strictly for ballast, they are vapor free and completely eliminate the generation of unloading emissions. The effective control efficiency is 100%. Although ships occasionally require more ballast than their segregated ballast capacity can supply, their segregated ballast capacity is generally sufficient to get them out to sea where ballasting emissions are much less of a problem.

The application of segregated ballast ships in gasoline service is not a problem. However, converting a nonsegregated ballasted ship to segregated ballast is a major undertaking and may not have any advantages over the application of shore-side recovery systems. Retrofitting segregated ballast capacity is expensive, and it results in reduced cargo capacity.

Short ballasting refers to the practice of only partially filling cargo tanks with ballast water. Normally ships with integrated ballast, ballast 40 percent of their tanks to 80 percent - 100 percent of capacity. In short ballasting, the ship would fill 40 percent of its tanks to 50 percent of capacity, and take on the remaining needed ballast after they are out to sea. Adverse weather conditions would of course preclude the practice of short ballasting.[23]

The control efficiency of short ballasting will vary from 50 percent to 100 percent depending on the degree of vapor stratification experienced in the cargo tank. Under high stratification as experienced by British Petroleum, the efficiency of short ballasting will be very high.[23] Under conditions of well mixing as measured by Radian Corporation, the efficiency will be much closer to 50 percent.

6.0 NATIONAL HYDROCARBON REDUCTIONS FROM OPERATIONAL CONTRAL TECHNIQUES

Hydrocarbon emissions occur at marine terminals when crude oil or gasoline are either loaded onto or unloaded from tankers and barges. To accurately calculate the hydrocarbon emissions for a particular vessel requires precise data on the amount transferred, the transfer procedures, and the cruise history of the tanks. With the exception of special field sampling programs, this type of data is rarely available. However, emission factors based on the test data recorded during such field sampling programs can be used to estimate the hydrocarbon emissions from a vessel when loading and unloading volatile hydrocarbon products under a given set of circumstances.

The only reliable emission factors which are available pertain to hydrocarbon emissions resulting from the loading of gasoline. Due to insufficient test data, there are no reliable emission factors for estimating hydrocarbon emissions when unloading gasoline or when loading or unloading crude oil. Consequently, present and anticipated future national emissions are calculated only for the case of gasoline loading on tankers and barges.

6.1 Estimated Hydrocarbon Emissions from Gasoline Loading in 1975

In 1975 approximately 228 million barrels of gasoline were loaded on tankers and barges in U.S. ports. Although this figure applies only to interstate movements of gasoline, it is thought to be a fairly representative estimate of the national total. Most of the gasoline loading (92%) occurred at Gulf

Coast ports, while only minor amounts (4% each) were loaded on the East Coast and on the Great Lakes and Inland Waterways. No significant gasoline loading of ships and barges occurred at West Coast ports.

In estimating the hydrocarbon emissions from gasoline loading operations three levels of control were considered:

- Uncontrolled (UNC) -- Assumes all tanks are dirty and no attempt is made to regulate loading rates or to contain the vapor blanket by short loading. The proper emission factor is 2.4 lb/10^3 gal (see Table 5.1-5) for tankers and 4.0 lb/10^3gal for barges.

- Present Operating Controls (POC) -- Assumes a present mix of tank conditions, including clean, ballasted, and dirty. POC also assumes no attempt to regulate loading practices. The emission factors are 1.2 lb/10^3 gal for tankers and 4.0 lb/10^3 gal for barges.

- Complete Operating Controls (COC) -- Assumes the tanks of ships have been cleaned, the initial loading rate was slow, and all tanks were short loaded. For barges, the tanks were dirty, the initial loading rate was slow, and the tanks were completely filled. Cleaning and short loading of barge tanks is considered impractical. The emission factors are 0.2 lb/10^3 gal for tankers and 3.3 lb/10^3 gal for barges.

Before these emission factors can be used to calculate the hydrocarbon emissions for a particular region, the mix of tanker and barge traffic must be known. Since no definitive statistics of this kind are available, it was necessary to estimate these traffic mixes according to the characteristics of a certain region. For example on the Gulf Coast, the states of Texas and Louisiana would be expected to have slightly different mixes of tanker and barge traffic. Texas predominantly exports gasoline to the East Coast. Thus, tankers account for the majority (95%) of the gasoline loaded on water carriers in this state. Louisiana, on the other hand, will barge a significant amount of gasoline up the Missippi River. Although tankers still account for a majority (80%) of the gasoline loaded on water carriers in Louisiana, the amount of barge traffic is well represented in the overall traffic mix.

The estimated national hydrocarbon emissions from gasoline loading in 1975 are summarized in Table 6.1-1. The emissions estimates are based on amounts of gasoline loaded on water carriers for interstate transportation only. It is important to note the rather large amount of hydrocarbon emissions contributed by marine transport of gasoline on the Great Lakes and Inland Waterways with respect to the total amount of gasoline loaded. Barges are the major type of vessel used in this region. Since barges cannot be cleaned, the arrival component of the loading emissions is always present. Therefore the impact of operating procedures is minimal and results in a larger degree of emissions with respect to volume loaded.

6.2 Estimated Hydrocarbon Emissions from Gasoline Loading in 1985

The amount of hydrocarbon emissions resulting from gasoline loading operations on tankers and barges in 1985 will

TABLE 6.1-1. ESTIMATED HYDROCARBON EMISSIONS FROM GASOLINE LOADING IN 1975

Region & State	Type of Vessel	Amount Loaded (10^3 BBL)	Hydrocarbon Emissions (Tons)		
			UNC	POC	COC
East Coast					
Delaware	Tanker	8,500	428	214	36
	Barge	1,500	126	126	104
		10,000	554	340	140
Gulf Coast					
Texas	Tanker	117,400	5,917	2,958	493
	Barge	6,179	519	519	428
Louisiana	Tanker	67,499	3,402	1,701	283
	Barge	16,000	1,344	1,344	1,109
Mississippi	Tanker	1,569	79	40	7
	Barge	523	44	44	36
		209,170	11,305	6,606	2,356
Great Lakes & Inland Waterway					
Ind. & Ill.	Barge	8,400	706	706	582
		8,400	706	706	582
West Coast		--	--	--	--
Total		227,570	12,565	7,652	3,078

depend heavily on the growth rate of refineries in the four geographic regions under consideration. It is this projected refinery capacity which directly determines the gasoline production and, subsequently, the supply/demand situation for a particular region. Using the data of Table 4.3-11 as a means of scale-up and assuming that transportation patterns and marine traffic mixes have not changed appreciably, the estimated hydrocarbon emissions from gasoline loading in 1985 were calculated and summarized in Table 6.2-1. Figures for the uncontrolled case (UNC) are not reported since by 1985 some form of emission control will almost certainly be in effect. The present operational controls case (POC) represents the projected 1985 national marine terminal emissions assuming a continuation of current loading practices. The complete operational controls (COC) case represents projected national emissions in 1985 under the application of applicable operational control techniques.

As before, the contribution of barges to the overall hydrocarbon emissions total is readily apparent. An interesting comparison can be made in Scenario II, which represents a minimum growth situation. Although the amount of gasoline loaded in Delaware is slightly greater than the amount loaded in Indiana and Illinois, the anticipated hydrocarbon emissions are considerably less. Under present operating controls (POC), Delaware experiences less than half the hydrocarbon emissions of Indiana and Illinois. If complete operating controls (COC) are employed, the difference is even more dramatic with Delaware experiencing approximately one fifth of the hydrocarbon emissions of Indiana and Illinois. The major difference is the type of vessel loading gasoline. Delaware loads mostly tankers, which can be cleaned to reduce the arrival component of hydrocarbon emissions. Indiana and Illinois will load only barges which do not have the facilities or crew to clean tanks.

TABLE 6.2-1. ESTIMATED HYDROCARBON EMISSIONS FROM GASOLINE LOADING IN 1985

Region & State	Type of Vessel	SCENARIO I			SCENARIO II		
		Amount Loaded (10^3 BBL)	Hydrocarbon Emissions (Tons)		Amount Loaded (10^3 BBL)	Hydrocarbon Emissions (Tons)	
			POC	COC		POC	COC
East Coast							
Delaware	Tanker	16,626	419	70	10,085	254	42
	Barge	2,934	246	203	1,780	150	123
		19,560	665	273	11,865	404	165
Gulf Coast							
Texas	Tanker	156,591	3,946	658	159,026	4,007	668
	Barge	8,242	692	571	8,370	703	580
Louisiana	Tanker	90,032	2,269	378	91,432	2,304	384
	Barge	21,341	1,793	1,479	21,673	1,821	1,502
Mississippi	Tanker	2,093	53	9	2,125	54	9
	Barge	698	59	48	708	59	49
		278,997	8,812	3,143	283,334	8,948	3,192
Great Lakes & Inland Waterway							
Ind. & Ill.	Barge	8,225	691	570	11,378	956	788
		8,225	691	570	11,378	956	788
West Coast		--	--	--	--	--	--
Total		306,782	10,168	3,986	306,577	10,308	4,145

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APPENDIX A
INDUSTRY CONTACTS

APPENDIX A - INDUSTRY CONTACTS

Company	Name	Title/Department	Address and Phone
Petroleum Industry Contacts			
American Petrofina, Inc.	Mr. Clarence Crow	Marketing	Box 2159 Dallas, Texas 75221 (214) 750-2708
	Mr. William H. Rode	Refinery Coordinator	Box 849 Port Arthur, Texas 77650 (713) 962-4421
	Mr. T. J. Lyden	Manager, Southeast Terminals	2970 Parrott Ave., N.W. Atlanta, Georgia 30318 (404) 794-7616
	Mr. Sam Hunnicutt	Manager, Harbor Island Terminal	Box 1311 Big Spring, Texas 79720 (915) 263-7661
Ashland Petroleum Company	Mr. Robert I. Lichtner	Manager, Transportation-Engineering Dept.	Box 391 Ashland, Kentucky 41101 (606) 329-3333
Atlantic Richfield, Co.	Mr. Harvey Grimes	Environmental Affairs	400 E. Sibley Harvey, Illinois 60426 (312) 333-3000
	Mr. Edward Stewart	Marine Transportation	515 S. Flower St. Los Angeles, California 90071 (213) 486-3511
Champlin Petroleum Company	Mr. Pat Sadler	Manager of Planning and Economics, Supply and Distribution	700 Houston Natural Gas Bldg. Houston, Texas 77002 (713) 651-0411
Cities Service Oil Co.	Mr. Ancal Neal	Marketing, Environmental Rep.	Box 300 Tulsa, Oklahoma 74102 (918) 586-3750

APPENDIX A - INDUSTRY CONTACTS (Continued)

Company	Name	Title/Department	Address and Phone
Continental Oil Company	Mrs. L. Martin	Surface Transportation	Box 2197 Houston, Texas 77011 (713) 965-2079
	Mr. Dale Breedlove	Operations Manager, Marine Facilities	Box 37 Westlake, Louisiana 70669 (318) 491-5159
	Mr. W. H. Kluss	Vice President, Marine	High Ridge Park Stamford, Conn. 06904 (203) 359-3500
Exxon Corporation	Mr. Gordon Potter	Marketing	Box 2180 Houston, Texas 77001 (713) 656-5207
	Mr. Lee Fuller	Refining	Box 3950 Baytown, Texas 77520 (713) 427-5711
Getty Oil Company	Mr. G. W. Druckenmiller	Distribution and Engineering Manager	660 Madison Ave. New York, New York 10021 (212) 832-7800
Gulf Oil Company	Mr. D. M. Langston	Director, Environmental Affairs (Marketing)	Box 2001 Houston, Texas 77001 (713) 226-1669
	Mr. James N. Brown	Manager, Marine Operations Supply & Transportation	2 Houston Center Houston, Texas 77002 (713) 226-3137
	Mr. A. P. Kowalik	Director, Environmental Affairs (Refining)	Box 2001 Houston, Texas 77001 (713) 750-3322
Marathon Oil Company	Mr. F. C. Aldrich	Manager Environmental Control Division	539 South Main Street Findlay, Ohio 45840 (419) 422-2121
Mobil Oil Corporation	Mr. Ron H. Stovner	Manager, Regulatory Compliance Product Supply & Distribution	150 East 42nd Street New York, New York (212) 883-4982

APPENDIX A - INDUSTRY CONTACTS (Continued)

Company	Name	Title/Department	Address and Phone
	Mr. D. P. Heath	Coordinator, Environmental Conservation	150 East 42nd Street New York, New York (212) 883-4242
Phillips Petroleum Co.	Mr. Bob Wheeler	Petroleum Supply, Marine	Phillips Building Bartlesville, Oklahoma 74004 (918) 661-4200
Shell Oil Co.	Mr. Ron Shamblin	Transportation Development	Box 2463 Houston, Texas 77001 (713) 220-6585
Standard Oil of California (Chevron)	Mr. Dick Perkins	Supply and Distribution	575 Market Street San Francisco, Calif. 94105 (415) 894-4404
Standard Oil of Indiana (Amoco)	Mr. R. P. Lennart	Manager, Transportation Planning	Box 6110 A Chicago, Illinois 60680 (312) 856-7782
Standard Oil of Ohio (Sohio)	Mr. Bruce A. McCrodden	Senior Environmental Specialist	Midland Building Cleveland, Ohio 44115 (216) 575-4444
Texaco, Inc.	Mr. W. J. Coppoc	Vice President, Environmental Protection	Box 509 Beacon, New York 12508
	Mr. John Weiland	Environmental Protection	Box 509 Beacon, New York 12508 (914) 831-3400
Union Oil of California	Mr. Dick Salisbury	Environmental Affairs	Box 7600 Los Angeles, Calif. 90054 (213) 486-7538
Marine Industry Contacts			
Gulf Trading and Transportation Co.	Captain Ed Marcus	Manager, Safety & Environmental Control, Marine	One Presidential Blvd. Bala-Cynwyd, Penn. 19004 (215) 667-9000
	Mr. M. O. Simmons	Director, Safety & Environmental Control, Marine	

APPENDIX A - INDUSTRY CONTACTS (Continued)

Company	Name	Title/Department	Address and Phone
IOT Corp.	Capt. Gisnel	Shipping	Pennwalt Building Philadelphia, Penn. 19102 (215) 864-1200
	Mr. David Buchanan	Barging	(215) 492-8100
Sun Transport, Inc.	Capt. J. H. Bates	Fleet Captain, Operations	Box 280 Claymont, Del. 19703 (215) 485-1121
Trade Associations			
American Petroleum Institute	Mr. A. E. Gubrud	Director of Environmental Affairs	Room 759 2101 L Street, N.W. Washington, D.C. 20037 (202) 457-7058
	Mr. J. K. Walters	Evaporative Loss Measurement Committee	
	Mr. V. K. Leonard	Transportation Division	
American Waterway Operators, Inc.			Suite 1101 1600 Wilson Blvd. Arlington, Va. 22209 (703) 841-9300
Association of Oil Pipelines	Mr. J. Donald Durand	General Counsel	Suite 1208 1725 K Street, N.W. Washington, D.C. 20006 (202) 331-8228
Maritime Research Information Service	Mr. Davis G. Mellor	Manager	2101 Constitution Ave., N.W. Washington, D.C. 20418 (202) 389-6687
Transportation Association of America	Mr. Bill Tupper	Data and Statistics	Suite 1107 1100 17th Street, N.W. Washington, D.C. 20036 (202) 296-2470
Transportation Institute	Mr. Luciano	Data and Statistics	923 15th St., N.W. Washington, D.C. 20005 (202) 347-2590

APPENDIX A - INDUSTRY CONTACTS (Continued)

Company	Name	Title/Department	Address and Phone
Government Agencies			
Environmental Protection Agency	Mr. Dick Ball	Office of Energy	Mail Code RD-681 401 M Street, S.W. Washington, D.C. 20460 (202) 755-0646
Federal Energy Administration	Ms. Pat Barr Holmes	Data Services	2000 M Street, N.W. Washington, D.C. 20461 (202) 254-8450
Great Lakes Commission	Mr. Albert Ballert	Director	2200 Bonisteel Blvd. Ann Arbor, Mich. 48109 (313) 665-9135
U.S. Coast Guard	Mr. Bill Campbell	Marine Engineer	
	Mr. Hale	Chief Warrant Officer, Shipping Commissioner's Office	Long Beach, California (213) 590-2375
	Lt. Powers		Galveston, Texas 77550
	Commander Wicks		Federal Building Houston Ship Channel Houston, Texas
U.S. Department of Commerce	Mr. Dennis Pike	Census of Retail Trade	Fourteenth St. & Constitution Ave. Washington, D.C. 20230 (202) 763-7038
Waterways Freight Bureau			Suite 402 1334 G Street, N.W. Washington, D.C. 20005 (202) 638-0476

APPENDIX B
ANNOUNCED REFINERY EXPANSION PLANS, 1976

APPENDIX B - ANNOUNCED REFINING EXPANSION PLANS, 1976

Company/Location	Type	Stage	PAD	AQCR	Capacity (bpd)
Hunt Oil (Tuscaloosa)[1]	E	C	III	4	15,000
Louisiana Land & Exploration (Mobile)[1]	N	C	III	5	30,000
Marion Corp. (Theodore)[2,3]	E	E	III	5	2,000
Standard Oil Co. (Pascagoula)[1]		C	III	5	54,000
Tesoro-Alaskan Petr. Corp. [2,3,5]	N		V	9	18,000
Delta Refining (Memphis)[2]	E		II	18	4,700
J&W Rfy. Co. (Tucker)[2]	E	C	III	22	6,000
California Oil & Purification (Ventura)[1,3,4]	N	E	V	24	15,000
Douglas Oil Co. Calif. (Paramount)[1]	E	C	V	24	15,000
Lundray-Thagard Oil Co. (South Gate)[2,3,6]	E		V	24	3,300
Standard Oil Co. Calif. (El Segundo)[1,2,3,4]	E	U	V	24	175,000
Standard Oil Co. Calif. (Richmond)[1,2,3,4]	E	U	V	30	175,000
Standard Oil Calif. (Perth Amboy)[1,2,3,4]	E		I	43	80,000
Gulf Oil Co. (Philadelphia)[2]	E		I	45	30,000
Rock Island Rfy. Corp. (Indianapolis)[1,2]	E	U	II	80	7,000
Gladieux Rfy. Inc. (Ft. Wayne)[2,1]	E	C	II	81	2,500
Somerset Rfg. Inc. (Somerset)[2,3,7]	E		II	105	1,600
American-Petrofina (Port Arthur)[2,3,4,8]	E	E	III	106	30,000
ECOL (Garyville)[2,3]	N		III	106	200,000
Exxon (Baton Rouge)[2,3,9]	E		III	106	11,000
Good Hope (Good Hope)[4]	E	U	III	106	50,000
Gulf Oil (Port Arthur)[1,2,4]	E	UorE	III	106	23,000
Kerr-McGee (Wynnewood)[1]	N	C	II	188	16,000
Champlin Petr. Co. (Corpus Christi)[1,2,3,4,10]	E	U	III	214	60,000
Sader Refining Co. (Corpus Christi)[2]	N		III	214	12,000
Sigmor (Three Rivers)[3]	N		III	214	10,000
Three Rivers Rfy. (Three Rivers)[2]	E	U	III	214	5,000

APPENDIX B - ANNOUNCED REFINING EXPANSION PLANS, 1976 (Continued)

Company/Location	Type	Stage	PAD	AQCR	Capacity (bpd)
Atlantic Richfield (Houston)[1,2,3,4,11]	E	U	III	216	93,000
Penzoil-United Inc. (Falling Rock)[1,2]	E	U	I	234	40,000
1977					
Mallard Expl. Inc. (Atmor)[1]	N	E	II	5	7,000
Energy Co. of Alaska (Fairbanks)[1,2,3,4,12]	N	E	V	9	25,000
Midland Corp. (Cushing)[3,4]	E	UorE	II	17	16,000
California Oil Purification (Ventura)[3,4]	E	E	V	24	15,000
Standard Oil California (Perth Amboy)[1,2]	E	E	V	43	30,000
Shell Oil Co. (Woodriver)[1]	E	E	II	70	30,000
Tenneco (Chalmette)[1,2,3,4,13]	E	E	III	106	30,000
Steuart Petr. Co. (Piney Point)[1,21]	N	P	I	116	100,000
Gulf Oil (Luling)[3,4]	N	P	III	212	30,000
Exxon (Baytown)[1,2,3,4,14]	E	U	III	216	250,000
1978					
Odessa Rfg. Inc. (Mobile)[1,4,15]	N	E	III	5	120,000
Crown Central Petr. Corp. (Baltimore)[1,16]	N	E	I	115	200,000
Dow Chem. Co. (Freeport)[2,3,4,17]	N,E	P	III	214	200,000
Hudson Oil Rfg. (Bayport)[1,18]	N	P	III	216	200,000
Hampton Roads Energy Co. (Portsmouth)[2,3,4,19]	N	P	I	223	184,000
Virco (St Croix)[4]	N	P		247	200,000
1979					
Pittston Co. (Eastport)[3,4]	N		I	109	250,000
Cascade Energy Resources (Rainier)[4]	N		V	193	200,000

APPENDIX B - ANNOUNCED REFINING EXPANSION PLANS, 1976 (Continued)

Company/Location	Type	Stage	PAD	AQCR	Capacity (bpd)
Wallace & Wallace (Tuskegee)[3,4]	N		III	2	150,000
Odessa Rfg. Inc. (Mobile)[1,4]	N		I	5	120,000
Tesoro-Alaskan Petr. Corp. (Kenai)[4,2]	E	P	V	8	17,000
PIMA (Phoenix)[3]	N		V	15	3,000
Atlas Processing (Shreveport)[4]	E	UorE	III	22	40,000
J&W Refining (Tucker)[3]	E		III	22	150,000
Penzoil (Shreveport)[2]	E		III	22	40,000
Atlantic Richfield (Wilmington)[4]	N	P	V	24	20,000
Newhall Rfg. (Newhall)[1,3,4,20]	E		V	24	4,000
Powerine Oil (Santa Fe Springs)[4,1]	E	E	V	24	25,000
Macario Indep. Rfy. (Carlsbad)[4,1]	N	P	V	29	100,000
Pacific Resources (San Diego)[3]	N		V	29	100,000
Urich (Martinez)[3,4]	N		V	30	30,000
In-O-Ven (New London)[3]	N		I	41	400,000
Pepco (Saybrook)[3]	N		I	42	400,000
Shell (Gloucester)[3]	N		I	45	150,000
Conoco-Dillingham Oil (Barbers Point)[4,1]	N	E	V	60	50,000
HIRI (Eua Beach)[4,1]	E	P	V	60	20,000
HIRI (Ohau)[3]	E		V	60	65,000
Texaco (Lockport)[3,4,1]	E		II	67	25,000
Clark (Hartford)[3]	E		II	70	4,000
JOC Oil (Romeville)[4]	N	P	III	160	200,000
Le Gardeur Int. (Braithwaite)[3,4]	N		III	106	300,000
Texaco (Convent)[3,4]	N		III	106	200,000
Gibbs Oil Co. (Sanford)[3]	N		I	110	250,000
Crown Central Petr. (Baltimore)[1,3,4]	N		I	115	200,000
Saber-Tex (Dracut)[3]	N		I	119	100,000
Granite State Refs. (Rochester)[3]	N		I	121	400,000
Olympic Oil Refs. (New Market)[3]	N		I	121	400,000
United Refining (West Branch)[3]	E		II	122	5,000
Lakeside Rfg. Co. (Kalamazoo)[1]	E	U	II	125	?

APPENDIX B - ANNOUNCED REFINING EXPANSION PLANS, 1976 (Continued)

Company/Location	Type	Stage	PAD	AQCR	Capacity (bpd)
New England Petr. (Oswego)[1,4]	N		I	158	200,000
Cirillo Bro. (Albany)[3,4]	N		I	161	20,000
Vickers Petr. Corp. (Ardmore)	E	U	II	188	60,000
Cascade Energy Resources (Portland)[1]	N		V	193	30,000
Charter Oil (St. Helens)[4]	N	P	V	193	30-50,000
Columbia Indep. Rfy. (Portland)[3]		P	V	193	50,000
Pacific Resources (Portland)[3]	N		V	193	50,000
Saber Rfy. (Corpus Christi)[2]			III	214	12,000
Amoco (Texas City)[4]	E	U	III	216	?
Charter Intl. (Houston)[4]	E	U	III	216	?
Hudson Oil (Bayport)[3]	N		III	216	100,000
Phillips Co. (Sweeny)[4]	E	P	III	216	65,000
Texas City Rfy. (Texas City)[4]	E	U	III	216	?
Hampton Roads Energy Co. (Portsmouth)[22]	N		I	223	184,000

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[1] HPI: February 1976

[2] OGJ: April 26, 1976

[3] PE-177; Trends in Refining Capacity and Utilization; December 1975

[4] EPA Listing

[5] OGJ = 18,000*; FEA = 17,000 (A star will indicate the value used in this table)

[6] OGJ = 6,800; FEA = 3,300*

[7] OGJ = 5,000; FEA = 1,600*

[8] OGJ = 26,000; FEA = 34,000; EPA = 30,000*

[9] OGJ = 11,000*; FEA = 10,000

[10] OGJ = 52,000; EPA, FEA = 60,000*

[11] HPI, OGJ = 95,000; FEA, EPA = 93,000*

[12] HPI, OGJ = 25,000*; FEA, EPA = 15,000

[13] OGJ = 35,000; HPI, FEA, EPA = 30,000*

[14] OGJ, HPI = Complete in 1976; FEA, EPA = Complete in 1977*

APPENDIX B - ANNOUNCED REFINING EXPANSION PLANS, 1976 (Continued)

[15] Uncertain on EPA listing

[16] EPA, FEA listed as uncertain

[17] OGJ, HPI = Complete in 1977; FEA, EPA = Complete in 1978*

[18] FEA listed as uncertain

[19] OCJ = 184,000; FEA, EPA = 175,000*; Uncertain due to opposition on environmental grounds

[20] FEA = 4,000*; EPA = 10,000

[21] FEA listed as planned but not constructed due to opposition on environmental grounds

[22] FEA listed for 1978; EPA opposed on environmental grounds (Washington Post 4-20-76)

Type: E - Expansion
N - New

Stage: P - Planning
E - Engineering
U - Under construction
C - Completed

APPENDIX C

PROJECTED REFINING CAPACITY BY AQCR

APPENDIX C - PROJECTED REFINING CAPACITY BY AQCR
(bbl/day)

AQCR	1975	1980		1985	
		Max	Min	Max	Min
2	-	-	-	150,000	-
4	31,875	46,875		46,875	
5	343,300	556,300	377,630	719,435	411,960
8	60,000	60,000	60,000	77,000	60,000
9	14,250	57,250	14,250	57,250	14,250
14	38,400	38,400	38,400	38,400	38,400
15	-	-	-	3,000	-
17	-	16,000	-	16,000	-
18	43,900	48,600	43,900	48,600	43,900
19	60,786	60,786	60,786	60,786	60,786
22	116,468	122,468	128,115	361,964	139,762
24	1,078,635	1,301,935	1,186,499	1,451,886	1,294,362
29	-	-	-	200,000	-
30	626,000	801,000	688,600	893,109	751,200
31	189,000	189,000	189,000	189,000	189,000
32	9,500	9,500	9,500	9,500	9,500
35	9,200	9,200	9,200	9,200	9,200
36	52,925	52,925	52,925	52,925	52,925
41	-	-	-	133,000	-
42	-	-	-	133,000	-
43	353,000	463,000	388,300	498,900	423,600
45	993,300	1,023,300	1,092,300	1,172,600	1,191,600
49	5,700	5,700	5,700	5,700	5,700
56	5,000	5,000	5,000	5,000	5,000
58	13,000	13,000	13,000	13,000	13,000
60	101,750	-	111,925	244,639	122,100
65	2,800	2,800	2,800	2,800	2,800
67	949,500	949,500	949,500	974,500	949,500
70	430,750	460,750	473,825	500,476	516,900
74	279,000	279,000	279,000	279,000	279,000
77	22,585	22,585	22,585	22,585	22,585
78	25,200	25,200	25,200	25,200	25,200
79	42,100	42,100	42,100	42,100	42,100

APPENDIX C - PROJECTED REFINING CAPACITY BY AQCR (Continued)
(bbl/day)

AQCR	1975	1980		1985	
		Max	Min	Max	Min
80	32,000	39,000	32,000	39,000	32,000
81	12,500	15,000	12,500	15,000	12,500
84	8,075	8,075	8,075	8,075	8,075
94	192,000	192,000	192,000	192,000	192,000
96	54,150	54,150	54,150	54,150	54,150
97	25,000	25,000	25,000	25,000	25,000
98	51,100	51,100	51,100	51,100	51,100
99	226,430	226,430	226,430	226,430	226,430
100	9,500	9,500	9,500	9,500	9,500
103	135,800	135,800	135,800	135,800	135,800
105	3,000	4,600	4,600	4,600	4,600
106	2,997,025	3,341,025	3,296,728	4,300,007	3,596,430
109	-	250,000	-	250,000	-
110	-	-	-	83,000	-
115	28,500	228,500	28,500	295,500	28,500
116	-	100,000	-	100,000	-
119	-	-	-	100,000	-
121	-	-	-	267,000	-
122	76,600	76,600	76,600	81,600	76,600
123	65,000	65,000	65,000	65,000	65,000
124	295,300	295,300	295,300	295,300	295,300
125	5,600	5,600	5,600	5,600	5,600
129	68,900	68,900	68,900	68,900	68,900
131	66,000	66,000	66,000	66,000	66,000
132	127,300	127,300	127,300	127,300	127,300
134	4,200	4,200	4,200	4,200	4,200
140	137,900	137,900	137,900	137,900	137,900
141	15,781	15,781	15,781	15,781	15,781
143	2,500	2,500	2,500	2,500	2,500
146	5,000	5,000	5,000	5,000	5,000
153	157,830	157,830	157,830	157,830	157,830
158	-	-	-	78,139	-

APPENDIX C - PROJECTED REFINING CAPACITY BY AQCR (Continued)
(bbl/day)

AQCR	1975	1980 Max	1980 Min	1985 Max	1985 Min
161	-	-	-	20,000	-
162	111,385	111,385	122,524	111,385	133,662
172	58,658	58,658	58,658	58,658	58,658
174	64,000	64,000	64,000	64,000	64,000
177	188,370	188,370	188,370	188,370	188,370
178	82,920	82,920	82,920	82,920	82,920
179	4,850	4,850	4,850	4,850	4,850
181	9,700	9,700	9,700	9,700	9,700
184	5,225	5,225	5,225	5,225	5,225
185	198,800	198,800	198,800	198,800	198,800
186	163,500	163,500	163,500	163,500	163,500
187	4,750	4,750	4,750	4,750	4,750
188	111,000	127,000	111,000	187,000	111,000
189	62,500	62,500	62,500	62,500	62,500
193	14,000	214,000	14,000	419,042	14,000
197	6,800	6,800	6,800	6,800	6,800
210	36,500	36,500	36,500	36,500	36,500
211	200,800	200,800	200,800	200,800	200,800
212	2,600	32,600	2,600	32,600	2,600
213	5,462	5,462	5,462	5,462	5,462
214	476,725	763,725	524,398	834,943	572,070
215	26,000	26,000	26,000	26,000	26,000
216	1,631,725	2,174,725	1,774,898	2,508,351	1,958,070
217	32,620	32,620	32,620	32,620	32,620
218	105,500	105,500	105,500	105,500	105,500
219	7,000	7,000	7,000	7,000	7,000
220	145,000	145,000	145,000	145,000	145,000
223	53,000	108,200	58,300	108,200	63,600
228	336,500	336,500	418,990	336,500	457,080
229	30,400	30,400	30,400	30,400	30,400
234	4,900	44,900	4,900	44,900	4,900
241	43,000	43,000	43,000	43,000	43,000
242	69,100	69,100	69,100	69,100	69,100
243	75,240	75,240	75,240	75,240	75,240
247	-	200,000	-	200,000	-